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ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item : A.4.1

Italy

PROSPECTS OF AN ENERGY POLICY FOR THE DEVELOPMENT OF SOUTHERN ITALY

By Professor Felice IPPOLITO,
Secretary General of the National Committee
for Nuclear Energy

Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

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PROSPECTS OF AN ENERGETIC POLICY FOR THE DEVELOPMENT OF SOUTH ITALY

National Committee for Nuclear Energy
Via Belisario, 15 - ROMA (Italy)
By Prof. Felice IPPOLITO - Secretary General of the National Committee for Nuclear Energy

Soon after the second world war the economic and social structures of South Italy were not much changed compared with those existing at the beginning of the century. The gap continued between North and South, as it was manifest in Italy since the times of the Union, a fact denounced during decades by famous historians, economists and sociologists, giving rise to vivid polemics and debates on the so called "Southern Problem".

The different political climate of the years immediately following the war brought forth the intervention of the State, whose action concerned mainly the agricultural development and the creation of new infrastructures. However, the prior choice of the latter type of intervention presumed, by itself, an ensueing process of industrialization, considered as the aim of the development policy, so that this first stage can be considered, as regards the type or the sectors in which the public investments have been chiefly affected (roads, water conduits etc.), as the stage of preindustrialization.

The transition to the next stage of real industrialization was effected through direct intervention of the State industry and the creation, still in course, of special poles of development, by means of which one tries to render possible an autonomous process of economic development.

In the sphere of this policy public initiatives with the aim of potentializing the energetic sector assume a particular importance. In this connexion it should be noted that the intervention of societies financially supported by the State in the development of the South took place not only in terms of quantity i.e. as a total colume of investments, but also in terms of quality i.e. as regards qualification of the investments, in view of a larger realization of the economic initiatives.

In the four years period 1958-1961 on the total of industrial investments amounting to 304, 5 billions of lire, 204, 9 billions of lire (about 67%) have been spent on the energetic sector.

The amount of such investments, although demonstrating the efforts made to meet the needs of an increased economic development, did not however reduce, to a great extent, the gap existing, as regards the production of energetic sources, primary and secondary, between North and South.

The Schedule below shows, in fact, that the percentage data referred to the disponibility of primary and secondary sources of energy in North and

Central Italy and in South and Insular Italy have not greatly changed in the years 1958-1961, but on the contrary, as regards the first ~~ones~~, the gap seems even more striking.

RATES OF INCREASE OF PRIMARY AND SECONDARY SOURCES OF ENERGY IN NORTH CENTRAL AND IN SOUTH AND INSULAR ITALY

Period 1958 - 1961

	North and Central Italy	South and Insular Italy	Italy
		Primary Sources	
1958	72, 81	27, 19	100
1961	74, 48	25, 52	100
		Secondary sources	
1958	71, 56	28, 44	100
1961	68, 40	31, 60	100

A little brighter seem, instead, the rates regarding the secondary sources with an increase in the South Regions from 28, 44% to 31, 60% of the national total.

Nevertheless, with reference to analyses effected on the results of the last decades and on the basis of the data exposed in regard of the last four years period, we can affirm that it will be difficult to fill the gap in the energetic field between North and South, unless applying - with particular reference to the South Regions - a larger and more organic utilization of a new source of energy : ~~the~~ nuclear energy.

Finally, owing to substantial deficiency in energetic resources in the South and to the impossibility of meeting future needs by means of traditional resources existing on the spot, the solutions offered by the utilization of nuclear energy are the most corresponding to the need of an ulterior substantial reduction of the gap in regard of the energetic potential between North and South and a more speedy and autonomous development of the entire Southern Region.

Recently, a series of facts have contributed to diffuse the opinion according to which the cost of production of electricity of nuclear origin would not correspond to those low levels prognosticated some years ago. Should this be true, it would

be necessary to reconsider all the ~~hopes~~ attached to nuclear energy as well as the programs that on the basis of ~~such hopes~~ had ~~found~~ their concrete start. And as in this connexion the factor "cost" is of most importance, to establish the truth or the contrary to what was states above is urgent. Without speaking of debates, that since years are taking place on an international level, on economic aspects of the production of electricity from nuclear sources, we shall but state that although the cost of the latter be at present 20% higher than the cost of traditional thermal energy, there are ~~actually~~ modifications being introduced in the nuclear tecnology and new materials are employed on a large scale, so that the time seems near in which the difference between the cost of electricity produced by means of conventional sources and the cost of electricity of nuclear origin will be abolished. On the basis of the most recent analyses on costs of a nuclear power plant, it seems, in fact, that by adopting a particular type of an American boiling water reactor, the plant could produce electricity at 5, 90 lire a KWh. And at normal conditions of working for 7.000 hours a year, an English power plant will be able to furnish, in about two years, electric energy at the cost of 4, 80 lire pro KWh.

And so, on the ground of the preceding considerations it appears prevident and economically rational, to build the future power policy in the South on the use of nuclear power plants.

To-day there are in construction in the South two big nuclear power plants at the total of 350 MWe the production of which is calculated in 2, 5 billions of KWh. They are : the power plant of Latina of the S. I. M. E. A. of 200 MWe and the plant of Garigliano of the S. E. N. N. of 150 MWe. A third nuclear power plant of the type PWR of the S. E. L. N. I. is in construction in Trino Vercellese, in Northern Italy. With this plant added, whose realization depends on the general stabilization of the power producing societies, Italy's producing capacity will reach 500 MWe. To express the production in KWh, these three plants are expected to furnish in 1965 from 3, 5 to 4 billions of KWh per year, covering wbout 4-5% of the total production.

As we are about to conclude this report, we would like to point aout that the actual effort in the electric sector will bear no fruits unless there is immediately a second program provided for fixing its goal at the year 1970. It is with reference to that year that ~~full~~ competitivity of electricity of nuclear origin and a further development of nuclear power plants, reaching the power of at least 1000 MWe more, ~~are~~ expected. From 1970 onwards, with tecnological improvements as prospected, the increase in electric power, especially in the South of Italy, will have to be ensured through the nuclear energy.

We conclude affirming that the part nuclear energy is bound to play in the process of economic development of the South of Italy is fondamental, as the nuclear power plants represent the foundation of all ~~the~~ modern and rational planning ~~in respect~~ of industrial development.

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Agenda Item: A.4.1

United States of America

ECONOMIC CRITERIA FOR EVALUATING POWER TECHNOLOGIES IN LESS DEVELOPED COUNTRIES

By Richard A. TYBOUT,
Professor of Economics,
The Ohio State University,
Columbus, Ohio, U.S.A.

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ECONOMIC CRITERIA FOR EVALUATING POWER TECHNOLOGIES IN LESS DEVELOPED COUNTRIES

No. 689
A.4.1

by

Richard A. Tybout
Professor of Economics
The Ohio State University
Columbus, Ohio, U. S. A.

I. INTRODUCTION

1. The objec. of the present paper is to indicate the general nature of criteria relevant for choice among power technologies in less developed countries. Special considerations for the emergent nations arise out of (1) abundant manpower and in some cases high unemployment, (2) high capital costs, (3) limited public budgets, (4) high foreign exchange requirements and (5) limited power markets. Each of these considerations is taken into account in the order given. The criteria for evaluation of power projects are developed from the standpoint of the interest of society or the nation as a whole rather than the management of an individual enterprise.

2. Economic criteria for the introduction of power technologies are similar to the criteria relevant for choice among alternative investments in general. The object in all cases is to provide the maximum benefits to society from the available land, labor and capital. Benefits are defined by the goals of a society and costs are defined by the natural resources and skills of a people, both of which change over time.

3. For present purposes, only economic goals will be considered in defining benefits. The most important economic goal is usually an increase in per capita gross national product. A second goal differing in relative importance among different countries is reduction of unemployment (whether concealed or conspicuous). One method of reconciling these goals is to exclude the wages of otherwise unemployed labor in determining costs of specific projects, thus assigning a value to the increase in employment equal to the cost of the previously unemployed labor. If this is done, an advantage will, of course, accrue to projects that increase employment.

4. A general solution to the problem of choice involves the maximization of the difference between costs and benefits for all the projects considered for installation in a given planning period. This involves the following steps: (1) the choice of projects to be considered whose net benefits appear sufficiently promising at first glance to warrant closer study; (2) the identification of benefits arising from each project and determination of the money value of such benefits throughout the life of the project; (3) determination of corresponding costs for each project; (4) the discounting of

both costs and benefits to adjust for differences in time at which they are experienced in each project; and (5) the maximization of the economy-wide excess of benefits over costs, subject to constraints. Step 5 consists in selecting those projects whose net benefits are greatest, within the limits imposed by available budgets, foreign exchange and any other constraints. The present paper is concerned primarily with steps 4 and 5. It assumes that steps 1, 2, and 3 have already been completed.

5. The net benefits from a project are the difference between its gross benefits, or the value of output, and its costs. Gross benefits may be considered as the total revenue from the sale of output or, if output is to be distributed without charge, as the equivalent value in money terms. When considering benefits from the over-all social point of view, proper allowance must also be made for benefits attributable to the project which accrue to others or to society as a whole. For example, in the case of a hydroelectric project, benefits from flood control are generally estimated.

6. Offsetting the benefits from each project are its costs. These consist of capital and the operating expenses, including labor, fuel, other materials and overhead. Taxes may be omitted as a cost when judging public projects, but they are included where a choice among projects is being made by a private business organization. As in the case of benefits, proper allowance must be made for costs attributable to the project, which would be borne by others or by society as a whole. Such costs might include labor training and family relocation.

II. NET BENEFIT MAXIMIZATION

1) The Time Element

7. The economic variables have two different temporal characteristics. Capital expenditures are typically made in a lump sum at the beginning of a project. Operating expenditures are incurred more or less continuously during the life of a project. Gross benefits are similarly received on a relatively continuous basis. Some way must be found to reduce these variables to a temporal common denominater.

8. Two general alternatives are available to take account of the time element. Either capital costs can be spread to an equivalent annual flow comparable with operating expenses, or operating expenses and the value of output can be telescoped to the same point in time as capital costs. The former is known as the annual flow approach; the latter is known as the present value approach. Both have special utility in different circumstances.

2) Annual Flow Method

9. Annual equivalent capital flows are calculated by dividing capital costs by $\sum_{t=1}^{n} \frac{1}{(1+r)^t}$, which will be referred to henceforth as the "discount factor." The terms in the discount factor have the following meanings: r represents time rate of discount, t is a running index of the number of years that have passed since investment in the project, and the term n represents the estimated life of the project in years. With capital costs reduced to an annual equivalent flow

they can be considered comparable with annual operating costs. Annual net benefits can then be readily calculated by subtracting all annual costs, including annual equivalent capital costs, from the annual value of output.

10. The results derived from the above calculations are the same as would be found by using the sinking fund method of calculating depreciation and separately including an explicit interest cost. The annual flow method of calculation described here is mathematically simpler and more correct in economic conceptualization, however, than the sinking-fund approach. Still another method of obtaining annual capital flows, the method of straight-line depreciation, is to be avoided when making cost comparisons between projects. Straight-line depreciation leads to large errors for such capital-intensive projects as hydroelectric plants.

3) The Rate of Time Discount

11. If capital is obtained by borrowing, then the rate of time discount is the rate of interest on the loan. Since power projects in less developed countries may require substantial amounts of imported capital, this rate of interest is often determined in a world market.

12. A different situation is found where capital is obtained by taxation. No interest is explicitly paid on capital obtained by taxation, but governments acting on behalf of their people will wish to invest with regard for the time preferences of individuals. The reason for taking account of time preferences is that a capital investment requires that current consumption be foregone. In place of current consumption is the stream of expected future outputs of the project. The rate of time preference reflects the disutility of waiting for these outputs to become available over the life of the projects and the uncertainties of the future.

13. Two kinds of considerations are relevant in choosing a numerical value of r, the time rate of discount: (1) the preferences of individuals based on their own utilities as affected by personal consumption and work patterns; and (2) collective needs as seen from an organic view of society. It can be shown that a rate of time discount based on consideration number (1) is approximated as the harmonic mean of the time rates of discount of the individuals who will benefit from the project. A social rate of time discount based on consideration (2) should take proper account of the welfare of future generations as well as individuals living today. Such a rate of time preference would seem to require that individual taxpayers be willing to sacrifice some of the satisfactions they anticipate in their lifetimes on behalf of future generations. Unfortunately there is no precise formulation known to the author that will reveal the empirical magnitude of this time preference. This is a matter on which governments must make their decisions with full recognition of the implications of their actions on the choice among alternative projects.

4) Numerical Example of Project Selection Using Annual Flows

14. The implications of the annual flow method are illustrated in Table I, which demonstrates the individual and joint effects of differences among three hypothetical power projects in regard to capital costs, operating costs, useful lifetimes and rates of time discount. The assumed values used for comparison are shown in Part A of Table I. The three projects include a hydro plant, a

TABLE I

Illustrative Examples of Production Costs and Net Benefit Calculations
for Three Alternative Power Plants of 10,000kw Capacity Each.
Assumed to operate 5,000 hours a year

Part A. Assumed Values

Plant	Cost (dollars) (1)	Expected Lifetime (years) (2)	All Operating Costs (mills per kwh) Total (3)	Labor (4)	Fuel (5)	Operation & Maintenance (6)	Annual Operating Cost (dollars) (7)
Hydro	5,000,000	50	1.0	0.8	0.0	0.2	50,000
Steam	2,000,000	30	8.2	2.2	5.8	0.2	410,000
Diesel	1,000,000	15	8.8	1.0	7.6	0.2	440,000

Note: Gross benefits(in the present case gross revenue) are assumed to accrue at the rate of 20 mills per kwh. The total value of annual output is 10,000 x 5,000 hours x $.02/kwh = $1 million.

Part B. Annual Flows (thousands of dollars)

Plant	Rate of Time Discount = 0% Gross Benefit (1)	Capital Cost (2)	Operating Cost (3)	Net Benefit (4)	Rate of Time Discount = 5% Gross Benefit (5)	Capital Cost (6)	Operating Cost (7)	Net Benefit (8)	Rate of Time Discount = 10% Gross Benefit (9)	Capital Cost (10)	Operating Cost (11)	Net Benefit (12)
Hydro	1,000	100	50	800	1,000	274	50	676	1,000	505	50	445
Steam	1,000	67	410	523	1,000	130	410	460	1,000	212	410	378
Diesel	1,000	67	440	493	1,000	96	440	464	1,000	132	440	428

Part C. Present Values (million dollars)

Plant	Rate of Time Discount = 0% Gross benefit (1)	Capital Cost (2)	Operating Cost (3)	Net Benefit (4)	Rate of Time Discount = 5% Gross Benefit (5)	Capital Cost (6)	Operating Cost (7)	Net Benefit (8)	Rate of Time Discount = 10% Gross Benefit (9)	Capital Cost (10)	Operating Cost (11)	Net Benefit (12)
Hydro	50.0	5.0	2.0	43.0	18.3	5.0	.9	12.4	9.9	5.0	.5	4.4
Steam	30.0	2.0	12.3	15.7	15.4	2.0	6.3	7.1	9.4	2.0	3.9	3.5
Diesel	15.0	1.0	6.4	7.6	10.4	1.0	4.6	4.8	7.6	1.0	3.3	3.3
Diesel with replacement	30.0	2.0	12.8	15.2	15.4	1.5	6.8	7.1	9.4	1.3	4.2	3.9

Source: Part A values assumed, except that column (7) derived as product of column (3) x 50,000,000 kwh, the assumed annual output of each plant.

Part B values derived as follows:
Columns (1), (5), and (9) -- See Note to Part A.
Columns (2), (6), and (10) -- Derived by dividing capital cost figures from column (1), Part A, by discount factor $\sum_{t=1}^{n} \frac{1}{(1+r)^t}$ By simple algebraic manipulation, it can be shown that $\sum_{t=1}^{n} \frac{1}{(1+r)^t} = \frac{1-(1+r)^{-n}}{r}$, the expression generally used for present value of annuity in mathematical tables.
Columns (3), (7), and (11) -- Annual operating costs are assumed to be constant over the life of each plant, hence these values are the same as those in column (7), Part A.
Columns (4), (8), and (12) -- Derived from preceding three columns.

Part C values derived as follows:
Columns (1), (5), and (9) -- Annual gross benefit cumulated over the lifetime of each plant and discounted at the indicated rate.
Columns (2), (6), and (10) -- Since capital outlay is assumed to be made at the initiation of the project and in one lump sum, the present value is equal to the actual outlay as shown in column (10, Part A, except for the "diesel value with replacement" figure which also includes the present value of a second diesel plant costing $1 million installed 15 years later.
Columns (3), (7), and (11) -- Derived as the present value of the annual operating cost figures indicated rate, i.e. multiplied by discount factor.
Columns (4), (8), and (12) -- Derived from preceding three columns.

steam plant, and a diesel plant. Of these, the hydro plant is the most capital intensive and has the lowest operating costs, and the diesel plant is at the other end of the scale in both of these regards. Although the particular values chosen for the example are hypothetical, they are not unrepresentative of actual conditions at many places around the world. The example is intended only as an illustration of methodology, and not to provide a basis for judgments regarding the relative economic merits of possible power plants either at particular locations or in general. 1/

15. Part B shows a comparison of annual flows, including annual equivalent capital flow costs for each of the three technologies. The principal point to be noted is the increase in the relative merits of the less-capital-intensive technologies, particularly diesel, as higher time rates of discount are considered. The hydroelectric facility continues to show greatest net benefits throughout the range of rates of time discount used in the table, but the effect of its great capital intensivity is clearly apparent in narrowing the net benefit differences. At still higher rates of time discount, the diesel plant would actually result in greater net benefits than the hydroelectric plant. The small difference in capital intensity, or relative proportion of capital to total costs, between steam and diesel accounts for the reversal in the relative ranking of these two technologies between 0 and 5 percent rate of time discount. For 2 or 3 percent rates, steam would result in greater net benefits than diesel.

16. A different result could have been obtained if different gross benefits had been assumed. For example, if the hydroelectric plant could only be constructed in a remote area with a low demand for electric power, or if stream flow were so irregular and output quality so poor that power could only be sold at low rates, the value of output might be only 10 mills per kilowatt-hour at the hydro plant busbar. Annual gross benefits for the hydro project would only be $500,000 and there is no interest rate at which it would be preferable to either of the other plants.

5) Comparison of Present Values with Annual Flows

17. Present values are defined as the worth of expected future outputs and costs when viewed from the standpoint of the present time. The present value of gross benefits is the yearly rate of gross benefits expected multiplied by the discount factor. The present value of operating expenses is the yearly rate of expected operating expenses multiplied by the discount factor. If capital investment is made at the point in time at which the present value is calculated, the investment itself is the present value of the investment and no multiplication by the discount factor is necessary for capital. It will be noted that present values differ from annual flows by a constant multiple, the discount factor. The economic significance of this difference, however, is quite considerable, as will be seen by reference to Part C of Table I.

1/ It may be argued that the example is unfair to steam and hydroelectric power generation on the grounds that both have lower per kilowatt-hour costs in larger sized installations. In an empirical study it would be appropriate to consider all sizes of power plants and map out the circumstances in which each is best. This, however, is not possible within the limits of the present analysis and is also not relevant for present purposes.

18. Part C gives the same comparison as Part B, but on the basis of present values. Consider the first three lines of Part C. The ranking of the steam and diesel projects is reversed from what it was in Part B at the 5 and 10 percent rates of time discount. The reason is easiest to see at the zero rate of time discount. As there shown, net benefits are more than twice as high for steam as for diesel. This is because the steam project lasts twice as long as the diesel project. At the zero rate of discount, no account is taken of time differences and the greater longevity of the steam project has an unqualified effect. Annual differences in net benefits are not great between the steam and diesel projects, but net benefits accumulate over twice as long a time for the steam project. The longer life of the steam project is thus responsible in large degree for its comparatively better showing than diesel at the 5 and 10 percent rates of time discount.

19. The fourth line of Part C shows present values for two diesel projects, the second to be installed fifteen years after the first, resulting in a combined total life of both diesel installations equal to the life of the steam project. (It will be noted that the value of capital continuously decreases due to time discounting of the second project.) If line 4 is used to represent the diesel facilities and is compared with line 2 representing the steam facilities, then the same ranking of the two projects results as in Part B, within the rounding error of the figures. (The apparent difference at the 5 percent rate of discount is due to rounding.)

20. If the same sort of comparison were made between the hydroelectric project and either of the other two projects, it would be necessary to make the replacements terminate after the same number of years. An alternative is to calculate the present value of infinite replacements and compare projects on this basis. 2/ It can be shown that the ratio of present values so calculated would be the same as the ratio of annual values using equivalent annual capital costs as previously described.

21. This does not lead to the conclusion that equal time periods must be employed in comparing public projects. As will be noted below, the present value method of comparison for projects with different lifetimes is superior for most practical problems of project selection. The principal object of Part C is to indicate wherein the annual flow and present value methods differ.

6) The Problem of Choice

22. The annual flow method of calculating costs is the best choice for ranking power projects when there are no restrictions on choice such as might arise from budgetary limits or scarce foreign exchange. That is to say, the annual flow method is satisfactory when benefits and cost comparisons are made in the abstract and in the absence of the economic restrictions normally attending project selection. On the other hand, where restrictions are effective, as in almost every practical problem of project selection, present values subject to constraints must be employed.

2/ This is, in fact, the approach used by Alchian, A. A., Economic Replacement Policy, Rand Corporation Report-224 (Santa Monica, California, 1952).

23. The choice of one technology in preference to another is usually made from the viewpoint of a single annual budget or, at most, a limited number of budgets from which a limited number of replacements are contemplated, not from a stream of costs and benefits the equivalent of which is infinite replacement. When comparisons of net benefits are made from a fixed point in time, the fact of greater longevity of one project over another is a point in favor of the longer lived project.

24. Secondly, the size of the annual budget from which expenditures are made on power projects is generally limited by a variety of factors outside the confines of the present discussion. Any project that gives a positive value for annual net benefits is worth the money put into it if there is no other use for the money. Actually, of course, there are usually other uses for the money, and so the problem becomes that of somehow taking account of alternatives foregone. For present purposes, it is necessary to avoid a part of this problem by taking as given a sub-budget devoted exclusively to power projects. A remaining part of the problem, which cannot be avoided, however, is the apportionment of the scarce funds in the sub-budget among power projects.

25. A third consideration is that foreign exchange often exercises an equally effective constraint on the choice of projects. Thermal power generating equipment, for example, may be available only through imports. This being the case, limits on foreign exchange must be considered in the same way as budgetary limits on investment funds. A related, though different problem arises when foreign exchange is used for fuel imports. 3/

26. Other constraints arise from complementarities and incompatibilities among power projects. As an example of complementarities, it might be preferable to install both a diesel and a small steam power plant in preference to a large single steam plant of the same total capacity in order to take advantage of the suitability of the two smaller plants to varying load factors in the power system. In such a case, the two smaller plants are complementary. Incompatibility, on the other hand, is reflected in the physical impossibility of constructing two different hydroelectric plants at the same site or the economic unsuitability of building two different power plants to satisfy the same demand.

27. Following a method described in detail by the author elsewhere 4/, the considerations listed in the foregoing paragraphs can be included in the analysis by ranking power projects according to equation 1. The method is presented here from the viewpoint of public project planning in an economy with

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3/ There is another context in which foreign exchange effects need not be considered for the planning of power projects. This is in the importing and exporting of power itself. Very little power moves in international trade and this is largely in the form of electricity across the borders of adjacent countries. Therefore, no account need be taken of foreign power costs or of potential competition by foreign suppliers in the domestic market. In this respect, the planning of power investments is different from that of most investments in manufacturing, agriculture and extractive industries.

4/ Forthcoming in United States publication of papers presented at this conference. The method on which the analysis is based is an adaptation of an approach developed by Steiner, P. O., "Choosing Among Alternative Public Investments", American Economic Review, Vol. 49 (December, 1959).

an important private sector. Adaptations of the method can be made for project selection in an economy without an important private sector and for project selection within a private business firm.

28. The method is based on a recognition that funds available for public power projects and foreign exchange have productive uses elsewhere. The object is to be sure that power project uses of funds and foreign exchange are more valuable than the alternative uses of the same funds and foreign exchange. With this end in view, the formulation makes two correctives. First is the corrective (represented by the term c_1k) for other productive uses of funds (backlog projects) in the power project budget. Second is the corrective (represented by the term c_2h) for other productive uses of foreign exchange. Each of these correctives can be determined empirically but not without a more extensive analysis than it is possible to report here. 5/

$$\bar{Z} = \bar{B} - c_1k - c_2h \quad \ldots\ldots\ldots\

TABLE II

Adjustment of Present Value of Net Benefits
(Figures are in millions of dollars except for the coefficients c_1 and c_2. Calculations are based on r = 5 percent)

Part A
(c_1 = 0.6, c_2 = 0.7)

	Hydropower		Steam		Diesel	
Net Benefits, $\bar{B}$		12.4		7.1		4.8
$c_1 k$	0.6x5.0 = 3.00		0.6x2.0 = 1.2		0.6x1.0 = 0.6	
$c_2 h$	0.7x0.3x5.0 = 1.05		0.7x0.8x2.0 = 1.12		0.7x0.8x1.0 = 0.56	
		-4.05		-2.32		-1.16
Adj. Net Benefits, $\bar{Z}$		8.35		4.78		3.64

Part B
(c_1 = 2.0, c_2 = 0.7)

	Hydropower		Steam		Diesel	
Net Benefits, $\bar{B}$		12.4		7.1		4.8
$c_1 k$	2.0x5.0 = 10.0		2.0x2.0 = 4.0		2.0x1.0 = 2.0	
$c_2 k$	0.7x0.3x5.0 = 1.05		0.7x0.8x2.0 = 1.12		0.7x0.8x1.0 = 0.56	
		-11.05		-5.12		-2.56
Adj. Net Benefits, $\bar{Z}$		1.35		1.98		2.24

Source: Values of net benefits, $\bar{B}$ are from Table I, Part C, Column (8), first 3 lines. Other terms are calculated according to equation 1 of the text using assumed values for c_1 and c_2 as indicated.

TABLE III

Total Net Benefits with Power Project Budget of $7.0 Million
(Figures are in millions of dollars, except for c_1 and c_2)

Part A
(c_1 = 0.6, c_2 = 0.7)

Hydropower	12.4	Hydropower	12.4
Steam	7.1	Diesel	4.8
$\bar{B}$	19.5	Backlog projects 0.6x1.0	0.60
		h adjustment 0.7x0.8x1.0	0.56
		$\bar{B}$	18.36

Part B
(c_1 = 2.0, c_2 = 0.7)

Hydropower	12.4	Hydropower	12.4
Steam	7.1	Diesel	4.8
$\bar{B}$	19.5	Backlog projects 2.0x1.0	2.0
		h adjustment 0.7x0.8x1.0	0.56
		$\bar{B}$	19.76

Source: Net benefits for hydroelectric, steam and diesel are from Table I, Part C, column (8), first 3 lines. Backlog projects and h adjustments are calculated as indicated using corresponding values of c_1 and c_2.

Table II, which is an extension of the example shown in Table I.

31. Table II uses the same present values for the same three power technologies as in the first three lines of Part C, Table I at the 5 percent rate of time discount. Part A of Table I assumes the following values for the coefficients: $c_1 = 0.6$ and $c_2 = 0.7$. It also assumes that eighty percent of the value of plant and equipment is imported ($h = 0.8k$) for diesel and steam power, but only 30 percent is imported ($h = 0.3k$) for hydropower. Part B of Table II is based on the same assumptions as Part A except that a value of $c_1 = 2.0$ is used. Although it is not possible to present here the details for calculation of the c_1 coefficient, the contrast between the values for c_1 in Parts A and B is clearly a contrast between a slack and a tight power project budget. The smaller the budget for power projects, all other things equal, the greater will be the value of any additional funds and hence of c_1.

32. Now, consider the following situation. Suppose the total available budget for powerplants is $7.0 million, that the hydroelectric plant is considered for one site and the diesel and steam plants are alternatives for another site. The requirement of compatibility prevents the construction of both diesel and steam plants, but does not prevent the construction of the hydroelectric plant and either of the other two.

33. According to the $\bar{Z}$ values shown in Table II, which are calculated following equation 1, the hydroelectric and steam projects should be constructed with $c_1 = 0.6$, while the hydroelectric and diesel projects should be undertaken with $c_1 = 2.0$. The implications of the adjustment of net benefits according to equation 1 are illustrated in Table III, where the total net benefits for each of the two alternative combinations of projects are shown for $c_1 = 0.6$ (Part A, Table III) and $c_1 = 2.0$ (Part B, Table III). The results confirm the preceding selection based on Table II. The highest total net benefits with $c_1 = 0.6$ are found in the hydroelectric and steam projects; with $c_1 = 2.0$, the highest net benefits result from expenditure on the hydroelectric and diesel projects. The $1 million that is freed by installing the diesel rather than the steam project is spent on backlog projects. The $0.56 million of foreign exchange that is freed by the installation of the diesel rather than the steam project is likewise channeled into other uses, which in this example are represented by the c_2 value of 0.7. It is clear that a variety of alternative considerations can influence the choice among the three technologies, involving different combinations c_2 as well as c_1 and different proportions of foreign exchange to total capital cost.

34. If the power projects budget were limited to $6.00 million, it would be necessary to choose between the steam project on the one hand and the hydroelectric plus diesel projects on the other hand. With either the Part A or Part B assumptions, the latter two would win out. A more difficult question is which project to choose if the budget is limited to $5.00 million. According to Table II, the hydroelectric project should be selected if $c_1 = 0.6$ and the diesel project if $c_1 = 2.0$. Calculations analogous to those shown in Table III will confirm the wisdom of these choices.

35. Finally, it is possible that the coal plant might come into more favorable standing as compared with the diesel plant even at values of c_1 in the range of those shown in Part B of Table II if diesel fuel must be imported and coal can be obtained from domestic sources. (The opposite, of course, would be true if coal had to be imported and diesel fuel were available at home.) To this

point, only the effects of foreign exchange on capital have been considered. A more difficult problem arises when foreign exchange is also used for fuel. 7/ This problem cannot be analyzed here except to note that uses of foreign exchange for fuel can exert at least as important an effect on the choice of a power technology as uses of foreign exchange for capital.

III. APPLICATION OF CRITERIA

36. A complete analysis of alternatives should consider the effects of different sized installations of the different technologies. Larger scale production installations and lower production costs may be offset by the costs of distributing power over wider market areas. Although the examples have been limited to production cost comparisons, a proper application of the criteria must include transmission and distribution as a part of project costs. It is reasonable to expect that in early stages of economic development, the choice will tend to favor smaller projects because (1) there are few large high-density power markets and (2) transmission and distribution expenses are capital-intensive. Large power installations can be expected to become more numerous in later stages of economic development.

37. Application of the criteria may be complicated in some cases by complementarities between production and use of power. A hydroelectric project might be considered only in conjunction with the manufacture of primary aluminum, or a small diesel facility only in combination with a village refrigeration unit. Complementarities of power production projects with particular power using projects suggest the need for combining the power budget with the appropriate manufacturing budgets, at least for an evaluation of the combined production-use projects. Fortunately, however, production-use complementarities are the exception rather than the rule for power projects (in contrast to the situation in many manufacturing industries). Accordingly, the complications that result from combining budgets can be avoided in most circumstances.

7/ The problem is analyzed by the author in the forthcoming United States publication referred to in footnote 4.

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DANS L'INTÉRÊT DES RÉGIONS PEU DÉVELOPPÉES

Point de l'ordre du jour : A. 3. 2. 1

Madagascar

LES ETUDES HYDROLOGIQUES SUR LE TERRITOIRE DE LA REPUBLIQUE MALGACHE, PRINCIPALES STATIONS TELEPHERIQUES DE JAUGEAGES

Par M. ALDEGHERI,
Hydrologue,
Maître de Recherches à l'Office de la Recherche
Scientifique et Technique Outre-Mer

Les mémoires rédigés à l'intention de la Conférence des Nations Unies sur l'application de la science et de la technique dans l'intérêt des régions peu développées sont des documents de travail. Ils sont publiés tels qu'ils ont été présentés et les assertions et opinions qu'ils contiennent sont celles de leurs auteurs.

NOTES

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LES ETUDES HYDROLOGIQUES SUR LE TERRITOIRE DE LA REPUBLIQUE MALGACHE

PRINCIPALES STATIONS TELEPHERIQUES DE JAUGEAGES

par

M. ALDEGHERI, Hydrologue
Maître de Recherches à l'Office
de la Recherche Scientifique et
Technique Outre-Mer

I. LES ETUDES HYDROLOGIQUES sur le TERRITOIRE de la REPUBLIQUE MALGACHE.

Les prémières observations hydrologiques ont été effectuées par la Mission E.D.F. en 1948-49. Elles ont été reprises en 1951 par le Service Hydrologique de l'Institut de Recherches Scientifiques de Madagascar (I.R.S.M.).

Leur but est de déterminer les différentes caractéristiques du régime des rivières, en vue d'apporter les éléments nécessaires à l'établissement de projets d'aménagements hydroélectrique ou hydro-agricole par exemple.

Le Service Hydrologique de Madagascar exploite 54 stations que nous pouvons classer en :

17 stations principales
22 stations secondaires
15 stations de troisième ordre

La répartition des stations sur les différents bassins est la suivante :

Bassin de l'IKOPA-BETSIBOKA	11	stations
" du MANGOKY	8	"
" MANDRARE	7	"
" de la TSIRIBIHINA	2	"
" de l'ONILAHY	2	"
" de la MANANJARY	2	"
" du MANGORO	2	"
" SAMBIRANO	2	"
" de la RIANILA	2	"
Bassins divers (Côte Est, Sud & Nord)	16	"

Chaque station est équipée d'une échelle limnimétrique en métal émaillé montée sur U P N de 80 mm. Ces échelles sont lues trois fois par jour par des observateurs demeurant à proximité. Huit stations ont leur échelle doublée par un limnigraphe.

Les jaugeages sont généralement effectués à l'aide de canots pneumatiques ZODIAC équipés de treuils NEWA, saumon de 25 kg et moulinet OTT. Le câble matérialisant la section est tendu avant chaque mesure.

Pour les grands fleuves : BETSIBOKA, IKOPA et MANGOKY, nous avons installé des stations de jaugeages par téléphérique dont la description détaillée est donnée plus loin.

Les observations sont continues et sérieuses sur une quarantaine de stations.

La caractéristique essentielle de la majorité des fleuves de Madagascar est la mobilité de leur lit. Il est difficile dans ces conditions d'obtenir des étalonnages définitifs.

Actuellement, on peut considérer qu'il existe une vingtaine de stations à fond stable qui sont étalonnées d'une façon définitive ce sont : les stations de l'IKOPA (Antsatrana, Bac de Fiadanana, Bévomanga), la BETSIBOKA à Ambodiroka, la NAMORONA à Vohiparara, l'IVOANANA à Fatihita, l'ANDROMBA à Tsinjony, la SISAONY à Andramasina, etc...

Parmi les stations à fond instable nous avons en particulier, la station du Banian sur le MANGOKY, où plus de 300 jaugeages ont été effectués depuis le début des observations. Nous obtenons chaque année un faisceau de courbes d'étalonnage qui rend l'exploitation particulièrement difficile.

Pour permettre une meilleure connaissance des relations entre les écoulements et les différents facteurs : pluviométrie, nature du sol, pente, végétation etc... nous avons procédé depuis 1954 à des études sur Bassins Versants Expérimentaux. Ces Bassins ont une surface comprise entre 2 et 30 km^2 et sont équipés de pluviomètres Association, de pluviographes destinés à l'étude de la pluie (répartition dans l'espace et dans le temps, intensité, etc...).

A l'exutoire du Bassin se trouve la station de mesure généralement équipée d'un seuil en béton, d'une échelle de crue et d'un limnigraphe à durée de rotation journalière.

Ces observations permettent d'obtenir pour chaque averse les coefficients de ruissellement, les temps de concentration etc... Nous essaierons également, en collaboration avec la section pédologique, d'établir les bilans hydriques des bassins.

Ces mesures sont complétées par l'étude de l'évaporation sur Bac Colorado et Bac Classe A. Nous exploitons actuellement cinq stations d'évaporation.

Les résultats de ces études ont fait l'objet de publications.

De plus, dans l'Annuaire Hydrologique de la Communauté et Pays d'expression française, sont publiés depuis 1950 les caractéristiques hydrologiques d'une quinzaine de stations de la République Malgache.

II. PRINCIPALES STATIONS TELEPHERIQUES DE JAUGEAGES.

Les fleuves de Madagascar connaissent des crues brutales et de courte durée. Les vitesses du courant sont fortent et égalent facilement 4 et 5 m/s (12 and 15 ft/sec), même aux endroits où sont installés les stations de jaugeage.

Les mesures de débit sont, de ce fait, difficiles à réaliser, souvent dangereuses à cause des arbres et débris divers charriés en grande quantité par la rivière.

Nous avons donc été obligés d'adopter pour les grands fleuves BETSIBOKA, IKOPA et MANGOKY, la solution de la station téléphérique de jaugeage. Ces installations coûteuses sont justifiées par l'ampleur des projets ayant pour base ces études. Leur prix de revient est d'environ un million de francs C.F.A.

Nous allons donner la description détaillée de l'une d'elles, celle de la BETSIBOKA à AMBODIROKA.

a/ STATION de la BESTIBOKA à AMBODIROKA

i/ Matériel utilisé

Le câble porteur est en acier fondu de 22 mm (.87 in.) de diamètre. Il est constitué par une âme de 5 mm (.2 in) entourée par 18 brins de 4 mm (0.16 in). Il pèse 1,5 kg au m/linéaire (1 lb per foot). Sa résistance à la rupture est au moins égale à 25 tonnes (25 tons). Les câbles tracteurs ont un diamètre de 6 mm (24 in).

Les manoeuvres de translation et de descente du saumon sont effectuées avec des treuils doubles DONAU OTT, actionnés par une seule manivelle.

Le saumon OTT de 100 kg (220 lbs) est suspendu à un câble électroporteur de 3 mm (.12 in) à un conducteur isolé.

Les mesures de vitesses ont été effectuées avec un moulinet OTT type ARKANSAS et un moulinet DUMAS NEYRPIC magnétique. Les tops sont comptés à l'aide d'un compteur à impulsion OTT type F 6 GARONNE.

ii/ Implantation

La station d'AMBODIROKA est située à environ 800 m ($\frac{1}{2}$ mile) en aval des chutes, soit à 2 km (1.2 mile) du pont de la route TANANARIVE-MAJUNGA.

Deux plate-formes de 10 m x 10 m (33 x 33 ft) ont été creusées dans les berges qui sont très escarpées.

Les massifs d'ancrage ont la forme d'un tronc de pyramide d'un volume de 12 m^3 environ. La face frontale a une surface de 6,5 m^2.

Les fers sur lesquels viennent s'articuler les tendeurs sont noyés dans le béton avec des morceaux de rails pour répartir les efforts.

Le câble de 22 mm (.87 in.) a été passé en étiage sans trop de difficulté. La mise sous tension provisoire a été réalisé à l'aide d'un treuil amarré à un ancrage.

Les tendeurs livrés avec tout le matériel ayant une course de réglage de 1 m (3,5 ft) avec filetage Withworth 1 ¼ - 2 ½, ont permis très facilement de donner au câble sa flèche définitive égale en moyenne à 5,50 m (17 ft) avec une charge de 120 kg (265 lb.).

iii/ Essais

Nous avons effectué des essais avec des saumons dont les poids varient de 10 à 175 kg (22 to 386 lb.). Nous avons réalisé plusieurs séries de mesures dans le courant de la journée avec des températures différentes. Pour chaque série, la température du câble varie très peu et nous avons admis qu'elle est constante.

Les courbes de variation de la flèche sont données sur le graphique n° 1.

La tension du câble est la résultante de la tension due à la charge répartie (poids du câble seul + effort du vent) et de la tension due au poids du chariot et du saumon.

Nous calculerons les tensions en appliquant la formule des câbles tendus :

$$T = \frac{L}{4\,f} \left(P + \frac{Q}{2} \right)$$

dans laquelle P désigne la charge concentrée, Q la charge répartie, f la flèche et L la portée du câble.

Pour déterminer la portée exacte entre appuis, nous avons adopté la méthode suivante : un câble de 3 mm (0.12 in.) a été placé à l'aide d'un petit treuil exactement entre les points de fixation du gros câble. Nous avons mesuré la flèche de ce filin lorsqu'il était tendu au maximum eu égard à sa résistance à la rupture. Nous avons repéré la longueur du câble de façon à lui donner une flèche correspondante à celle du gros câble et noté la longueur déroulée. La même opération a été répétée lorsque le câble de 3 mm (0.12 in.) touchait l'eau.

Les mesures de flèche ont été effectuées en étiage, le saumon hors de l'eau. Il n'était en effet pas possible de réaliser ces opérations en crue.

Le câble tracteur a son point le plus bas à 1 m (3.3 ft) au-dessous du câble porteur. Il se situe, dans le cas le plus défavorable (T 32° P = 175 kg) (386 lbs.), à 2,50 m (7.6 ft) au-dessus du niveau des plus hautes eaux.

Sur la BETSIBOKA, les arbres charriés en crue ne sont jamais très importants et cette garde est suffisante.

Au moment des jaugeages le saumon immergé reçoit une poussée assez forte due au courant et aux herbes qui peuvent s'accrocher au câble.

Dans ce cas, avec un saumon de 175 kg (386 lbs.) et en admettant qu'on puisse effectuer un jaugeage par un vent de 100 km/h (62 mi. per hour) exerçant sur une surface cylindrique une pression de 80 kg/ m^2 environ, le câble sera soumis à une charge répartie égale à 570 kg.

Dans ces conditions, le câble aura une flèche de 6,50 m (19 feet) correspondant à une tension de 7 tonnes (6.9 tons).

b/ STATIONS de l'IKOPA à ANTSATRANA et du MANGOKY au BANIAN

La station de l'IKOPA à ANTSATRANA est tout à fait comparable à celle d'AMBODIROKA. Le même matériel a été utilisé et les ancrages sont du même type. La portée du téléphérique est cependant un peu plus faible : 217 mètres (712 ft) au lieu de 245 mètres (803 ft).

La station téléphérique du MANGOKY au BANIAN a, au contraire, une portée beaucoup plus grande qui atteint 425 mètres (1390 ft), un câble porteur de 16 mm (63 in.) a été utilisé, sa résistance à la rupture est de 15 tonnes (15 tons). Sa flèche atteint 10,50 m (34.4 ft) en utilisant un saumon de 100 kg (220 lbs.). Pour réduire cette flèche on a installé un second câble ancré plus haut sur les berges qui sont assez escarpées. Ce nouveau câble soutient le premier en son milieu et réduit sa flèche d'environ 5 mètres (16.4 ft).

c/ DIFFICULTES RENCONTREES

i/ En cours de montage

La mise en place de ces trois stations s'est effectuée, dans l'ensemble, sans trop de difficulté.

Le passage et la mise sous tension d'un câble de 22 mm (.86 in.) est une opération délicate, bien sûr, mais qui se réalise assez facilement même avec les moyens réduits dont nous disposions.

Deux accidents qui auraient pu être graves sont cependant à signaler :

- Rupture du câble auxiliaire de 10 mm (.4 in.) servant à la mise sous tension provisoire du câble d'AMBODIROKA. Cette rupture s'est produite au moment où nous fixions les serre-câbles avant de procéder à la tension définitive avec les tendeurs. Il n'y a eu que quelques égratignures sans gravité.
- Rupture d'un serre-câble sur le câble tracteur du BANIAN au moment où il était presque sous tension normale. Cette rupture a entraîné la chute du câble dans le fleuve et la récupération a été assez laborieuse.

ii/ En cours d'exploitation

Les stations téléphériques permettent de réaliser les mesures de débit, dans les conditions les plus difficiles, en toute sécurité pour les opérateurs. Cependant, ces mesures sont très longues. Un jaugeage en crue sur la BETSIBOKA et l'IKOPA dure en moyenne 4 heures et 8 heures sur le MANGOKY.

La précision des mesures est liée à la façon dont peut être repérée la position du fond. Il est nécessaire pour arriver à un bon résultat d'équiper les saumons d'un contact de fond solide et sensible.

Un bon contact de fond a, de plus, l'avantage d'éviter l'ensablement du moulinet.

Une autre précaution très utile consiste à fixer le moulinet à 20 cm au moins au-dessus du saumon. Le montage en bout de saumon est à rejeter.

Il est recommandé d'utiliser un moulinet qui n'ait pas tendance à s'ensabler. Le moulinet DUMAS-NEYRPIC magnétique nous a donné les meilleurs résultats à ce point de vue.

Nous avons eu également des ennuis au début de l'exploitation avec un câble électroporteur qui n'était pas parfaitement antigiratoire.

Chaque fois qu'on le peut, il y a intérêt à utiliser le saumon le plus lourd possible, afin de diminuer l'angle fait par le câble électroporteur avec la verticale.

Pendant la mesure, il est nécessaire de surveiller en permanence la surface du plan d'eau et d'observer les corps flottants susceptibles de venir heurter le câble. Il est prudent de ne pas hésiter à relever rapidement le saumon dans le cas où on n'est pas très sûr de la trajectoire des arbres, qui, à 200 m (660 ft) est souvent difficile à déterminer.

Contrairement à ce qu'on pourrait croire, les jaugeages par téléphérique ne sont pas des opérations simples. Elles demandent une attention de tous les instants.

Le principal avantage de ces installations réside dans le fait qu'on peut toujours opérer par n'importe quel temps. C'est souvent très intéressant, surtout sur des rivières à crues très rapides.

181 F - Nov. 1962 - 1,000

NOTES

1. Papers selected for inclusion in General Sessions will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

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DATA AND INFORMATION ON GEOTHERMAL PLANTS

by

Dr. Niccolò GENNAI
Larderello S.p.A.

It is not necessary, in my opinion, to narrate again the history of Larderello at this Conference, since this town is already well-known all over the world for its typical resources and for the original applications of endogenous steam in the production of electrical energy and in the utilization of by-products.

However, it may be interesting to draw a brief outline of the most important datas of the research and of the utilization with regard to their costs and to their variations up today.

Diagrams 1 and 2 show drilling costs from 1958 to 1961, and the quantities of steam found from 1951 to 1960. The graphs show a remarkable increase of drilling costs per meter, which affects the costs of each kg of steam. The causes of this variation are self-explanatory, if one considers the origin of the phenomenon. The steam forms certainly in deep strata as a consequence of reactions or exchanges of heat which generate a certain amount of hot fluid, mostly composed of water, which spreads to the upper layers and reaches the surface under particular physical conditions. This steam, through natural channels (fractures), rises to the surface winning the resistance which the strata oppose to its penetration losing energy and often even condensing; most of all, however, it spreads, thus enriching the most porous strata, that is those which offer favorable conditions and low resistance to the penetration.

At Larderello, geology is practically constant and the succession of soils is as follows:
- scaly clay
- anhydrite series
- permian schysts

If the scaly clay layer and the anhydrite series below are especially thick, amounts of steam coming from deep strata may accumulate over a certain period of time, in the anhydrite series. In fcat, caly is almost impermeable and the anhydrite series, much fractured, presents little resistance to the circulation of steam; thus, natural reservers are formed.

Although early drillings at Larderello have discovered steam also in clay-covered layers, it is evident that the anhydrite series is the natural reservoir which, no matter how reached, is almost always in a position to supply steam.

Lowering the resistance which the steam encounters in its spreading by drilling artificial channels, most of the steam will converge toward these channels in order to rise to the surface, thus diminuishing or annulling the diffusion and the enrichment of these strata. In cultivation areas, this has the consequence of requiring deeper and deeper drillings in order to find new steamn and increasing proportionally the cost per drilled meter and the cost of each kg of steam found.

Remarkably deep drillings, up to 3000 m, have been performed at Larderello, with study purposes, but up to now they have given no positive results as far as the findings of steam are concerned. This may be explained by the fact that the anhydrite series was found beneath solid structures, which seem to exclude the possibility of a reservoir.

It is probable, however, that, if the drill could be made to fall upon a natural rise channel, the steam which could be carried to the surface would certainly have much higher pressure and temperature than that which is found in the porous stratum. Consequently, the discovery of stream in deep strata is more a matter of luck than of serious preliminary scientific studies.

From the geological viewpoint the soils crossed by the drill down to 3000 meters are the following:

- scaly clay
- anhydrite series
- permian schysts
- carboniferous schysts

Graph N. 3 shows the characteristic flow - time curve of three wells chosen among the average wells which, in our cultivation areas, are most indicative of the results of the drillings and their decrease in time. From these graphs it may be inferred that the life of an average well is longer than 10 years. Table N. 4 shows the kgs of steam measured in the years from 1950 to 1960 at the above-mentioned wells, and their finding costs. Therefore, an easy calculation of the cost of steam for each kWh may be performed by setting the following elements:

- average flow	30,000 kg/h
- well's life	10 years
- drilling cost	100,000 lire per drilled meter
- average depth	800 meters

In this case, since every ten years the same amount of steam as ten years before must be found, in order to keep the production of the basin constant, we have:

$$\frac{80,000,000}{15,000 \times 3,760 \times 10} = \text{L. } 0.06$$

+ 20% =	L. 0.060
	L. 0.012
	L. 0.072

Since for each kWh shall be L. 0.072. It must be pointed out that in each well the flow decrease until its exhaustion has nothing to do with the quantity of steam potentially existing in the basin itself. The decrease depends on various causes which reduce the diameter of the well and even choke it, while the amount of steam is practically invariable.

The cost of steam discovered for each kWh produced is a fundamental datum for comparison with other production systems. Table 5 shows the costs of geothermal centrals for the three production cycles. The costs of the

special equipment studied for an early quick utilization of steam in the zones where research is being performed are also added. Such movable equipment (monoblocs), fed by any kind of steam whatsoever - saturated, humid, over-heated - even with remarkable pressure differences, are fed directly and discharged by atmospheric pressure. They may be mounted within 50- 60 days and, though their specific consumption is far higher than that of the two above-mentioned cycles, they have the advantage of requiring little maintenance and personel, and of utilizing immediately the steam found, while waiting for the building of a stable plant, if later surveys shall prove it worthwhile.

This quick examination emphasizes the advantages of geothermal plants when previous studies, drills, surveys of the characteristic of the steam discovered, and utilization projects are performed by specialized personnel.

The genesis of the phenomenon confirms the possibility of finding steam in almost every part of the world. It also shows that this phenomenon lasts through millenia rather than centuries, and that the energy obtained is practically everlasting. Even though it is not possible to state that favorable conditions such as those found at Larderello exist all over the world, it is worthwhile to ascertain whether such possibilities exist.

Our International Relations office reports that geothermal plants have been set up in many countries (Mexico, built by Larderello S;p.A., New Zealand, North America, Russia, Iceland), confirming that steam may be found and applied in many parts of the world.

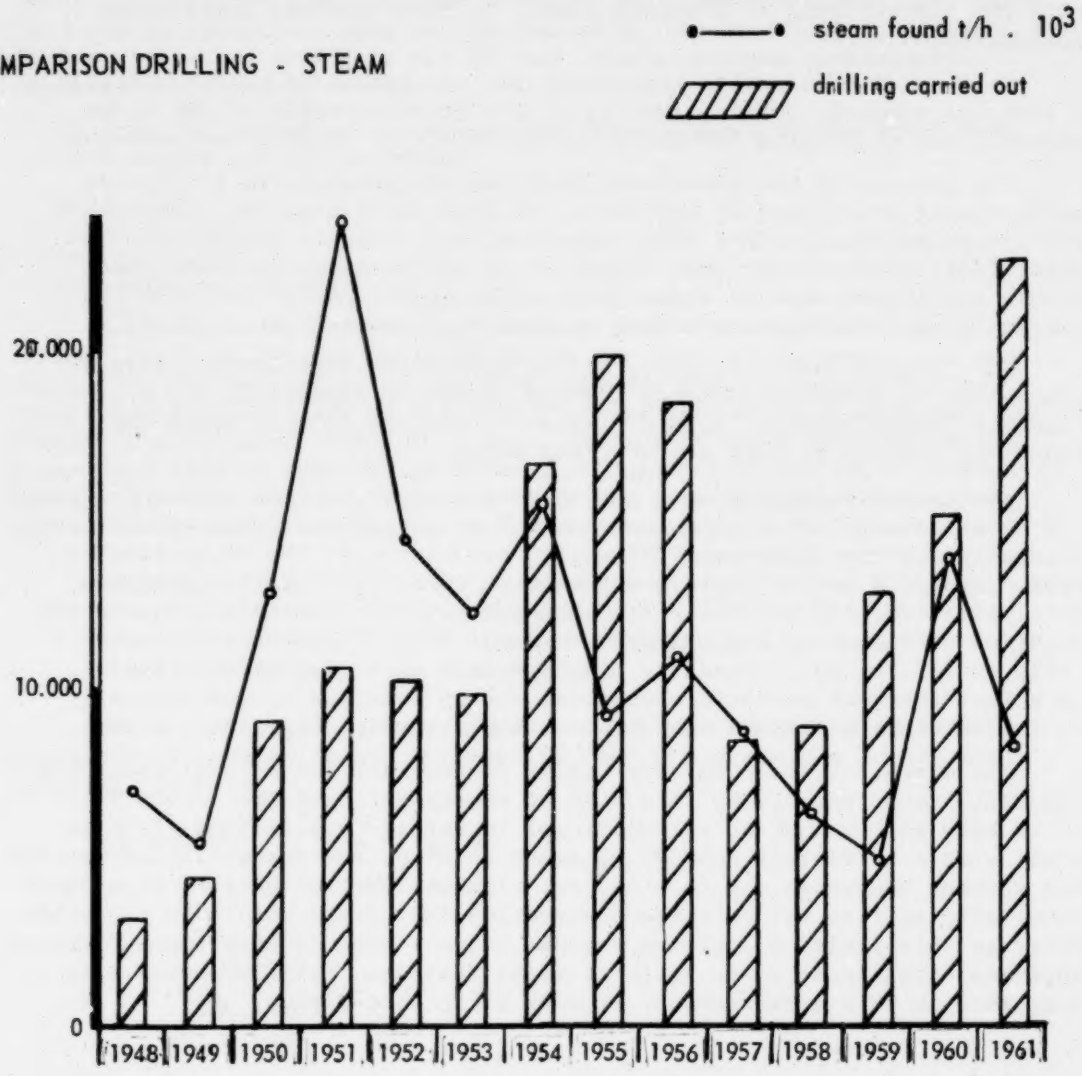
Geothermal energy appears not to have a local Italian interest anymore but an international importance, as a source of energy which may be utilized particularly for the improvement of social conditions of the population of depressed areas. A social improvement implies work opportunities, through industrialization. Independently from local resources, electrical energy may be supplied sufficiently and cheaply; we don't know if geothermal resources may help in filling this necessity, but they may certainly be very useful. It is a fact that, at present, electrical energy obtained by geo-thermal means is much less expensive than that obtained through any other process.

Therefore, it would be very useful to have all the information about the possibility of exploiting this kind of energy all over the world. In order to have such data, an international technical organization might be created, with a sufficient equip, in order to study the possibilities offered by the various countries and to study and plan utilization plants. It is not nationalistic spirit, but only the observation that Italy boasts an undoubted priority in this field, a positive example of achievements thoroughly skilled technicians, that leads us to think it right that the Italians should play a leading role in this organization, if ever it is established.

-

All values of steam and plant costs have been approximated to the nearest round number above.

COMPARISON DRILLING - STEAM



NOTICE: The remarkable differences in the comparison between the meters drilled and the amount of steam found are due to the fact that, in the various years, cultivation and research soundings are both taken into account. Their ratio changes seizeably from year to year.

Fig. 1

COMPARISON DRILLING - EXPENSE

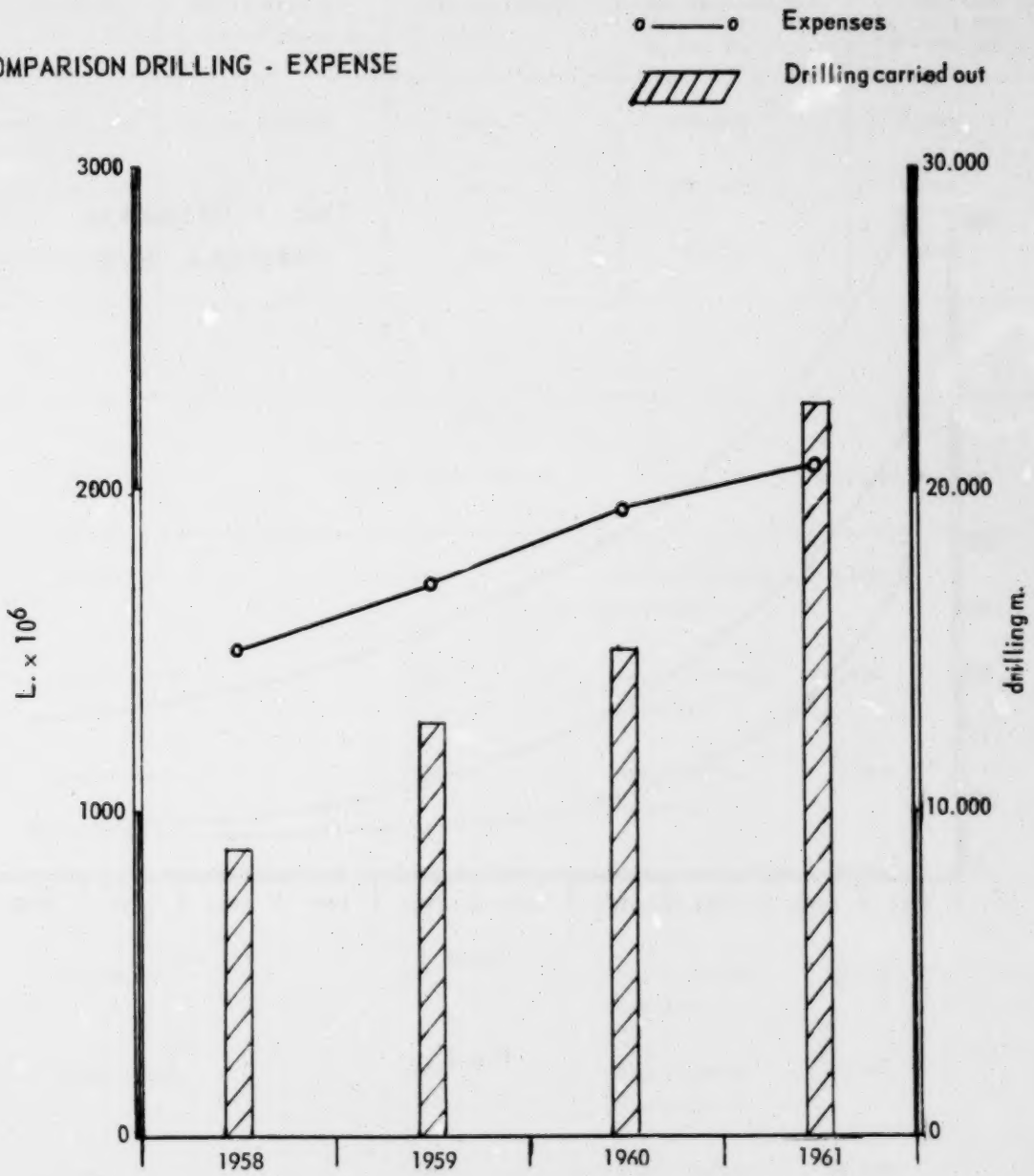


Fig. 2

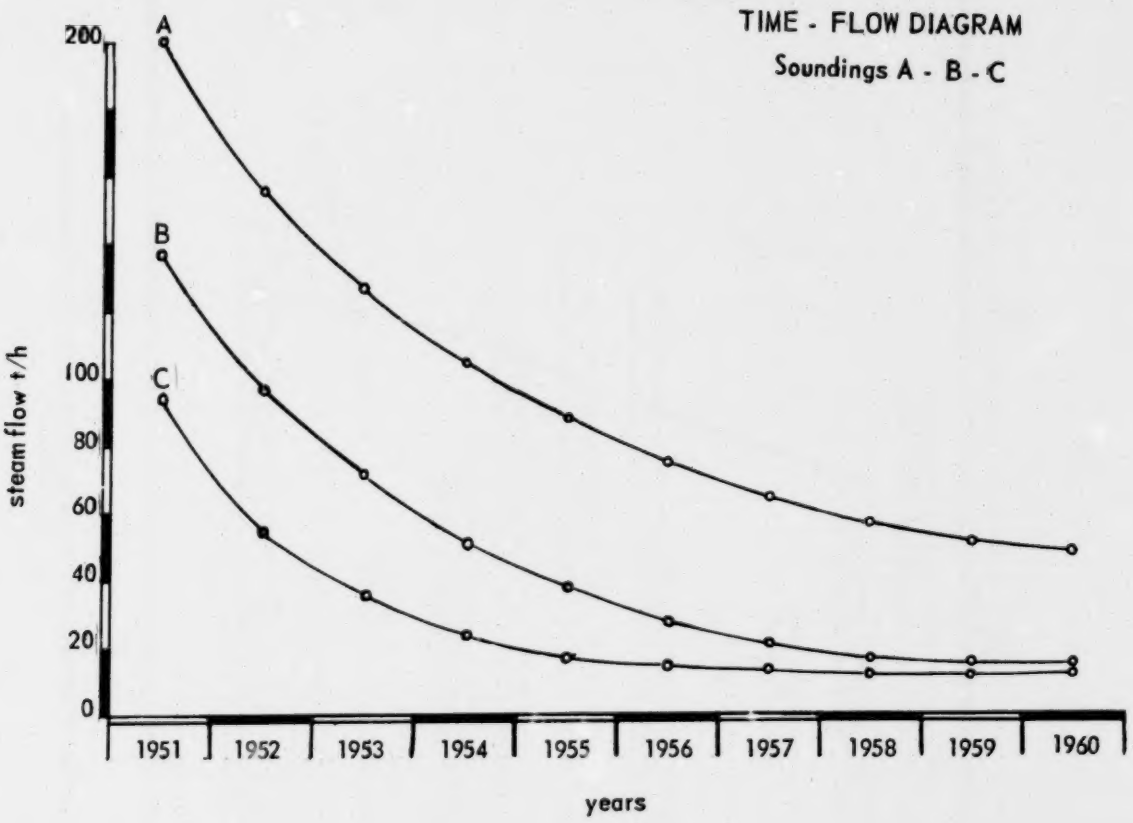

TIME - FLOW DIAGRAM
Soundings A - B - C
steam flow t/h
200
100
80
60
40
20
0
A
B
C
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
years

Fig. 3

COMPARISON OF COST PER METER AND COST PER KG OF STEAM ISSUED BY A FEW TYPICAL DRILLINGS

SOUNDING	(A) Total issue of kgs of steam in 10 years	(B) Average depth mt	(C) Average cost per drilled mt. L. per mt.	(D) Unitary cost per kg. of steam lire per kg.
Drilling (a)	8,514,720,000	800	100,000	0.009
Drilling (b)	4,283,640,000	800	100,000	0.018
Drilling (c)	2,522,880,000	800	100,000	0.032

$$D = \frac{B \times C}{A}$$

Fig. 4

Plant	Year of Construction	Cycle	Net cost per kWh
Larderello n. 2	1938	Indirect vacuum discharge	6,900
Castelnuovo	1942	Indirect vacuum discharge	6,850
Larderello n.3	1938	Direct vacuum discharge	31,000
Sasso Pisano	1958	Direct vacuum discharge	70,000
Serrazzano	1957	Direct vacuum discharge	70,000
Monterotondo	1959	Direct vacuum discharge	70,000
Lago	1960	Direct vacuum discharge	70,000
Monoblocco	-----	Direct discharge into the atmosphere	40,000

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Agenda Item : A.3.4.1

Italy

METHODS FOR OBTAINING WATER FROM THE ATMOSPHERE IN ARID LANDS

By Giorgio NEBBIA,
Istituto Merceologia Università
Bari, Italy

Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

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METHODS FOR OBTAINING WATER FROM THE ATMOSPHERE IN ARID LANDS

by

Giorgio NEBBIA

Instituto Merceologia Universitá

Bari, Italy

No. 2113
A.3.4.1.

1. The main approach to the problem of obtaining fresh water, mainly for domestic uses, in the arid lands is given - if no other source of water is available - by the demineralization of saline waters which are often available in such lands. Some important steps have been made for the solution of this problem and it is reasonable to believe that plants having capacities of thousends cubic meters per day will spread in the near future. The solution for particular conditions may be given by the use of solar energy and the problem is discussed elsewhere in this conference.

2. In the present paper a different approach will be indicated. The atmosphere is an enormous source of water which is present as vapor mixed with the gases of the atmosphere itself. The amount of water per cubic meter of air depends on the air temperature and renges - at the saturation - from about 8 gr/m^3 at 10°C to about 50 gr/m^3 at 40°C. The specific weight of humid air is less than that of dry air at the same temperature and this causes humid air to lift to the higher layers of the atmosphere.

3. The present psper discusses the problem of obtaining water from the atmosphere. Water condenses out of the atmosphere if the air temperature decreases because the amount of water which can be mixed with the other gases decreases.

4. The problem of obtaining water from the atmosphere is far from having been fully investigated: there are several approaches which can be summarized as follows:

a) Natural condensation of water from the air occurs when, during the night, a strong cooling of the ground surface takes place, generally because of nocturnal radiation from the warm earth to the clear night sky. There are several places on the Earth where this natural condensation occurs or seems to occur. The strong nocturnal radiation apparently depends on the structure of the ground.

b) Natural condensation of water occurs when air is forced in artificial devices in which some cooling takes place. This seems to have been a source of water in some ancient towns. A review of this phenomenom has appeared in the literature (2) (3) but its reproduction on a large scale has not so far been possible. It is also possible, although difficult, to obtain water condensation through artificial devices which radiate heat during the night. The knowledge on the nocturnal radiation and on the best radiating materials is still scarce. It must be noted, however, that in order to obtain appreciable amounts of water the air must have a high relative humidity and that the humid air is scarcely transparent to the heat radiation emitted by a body having a temperature of about 20 to 40°C; such body emits towards the nocturnal sky a radiation having a wave length in the range of 9 - 12 ft. On the contrary, if the air is dry a rather high heat radiation is possible but the condensation hardly

occurs. Some experimental work has recently been carried in Chile on this line (4) but a very poor condensation has been observed.

c) The condensation of water can be obtained by cooling air below its dew-point. The minimum theoretical energy consumption is given by the latent heat of vaporization, namely about 600 kcal/kg. of condensed water.

5. For the energy balance of this last method let us assume to use a refrigerating machine operated by a mechanical compressor and that the "figure of merit" (ratio of heat shifted by the engine to heat represented by the power input) of the machine is as favourable as 5 to 1. For such machine the energy consumption of the process would be about 120 kcal/kg (0.14 kwh/kg) of condensed water. If the compressor were driven by a Diesel engine using a fuel with a calorific value of 10,500 kcal/kg and with a yield of 33%, a 1 HP refrigerating machine would require $\frac{640}{0.33 \times 10,500} =$ 0.180 kg of fuel to obtain 5.3 kg of water per hour. In other words, 1 kg of fuel would give about 30 liters of water.

6. Wind energy seems attractive as a source of mechanical energy for operating a refrigerating machine. The Enfield Andreu wind motor should be considered with interest for this purpose (5).

7. Absorption refrigerators might also be used. If a fuel were burnt directly in a thermally actuated refrigerant machine the yield might be a little greater than if it were burnt in a Diesel engine driving a mechanical compressor. Solar energy might be used as a source of heat (6).

8. The above points show that the problem is attractive but that many variables must still be evaluated. In order to give a contribution to the problem of obtaining water from the air by cooling some experimental work has been carried using an electrically operated mechanical dehumidifier (7).

9. In the experimental unit the external air is caused by a fan to enter the air duct, having a section of 24 cm x 20 cm. The air flows on the evaporator coil, perpendicular to the air flow; the air is thus cooled below its dew point and water condenses on the evaporator surface. The cool saturated air then flows on the condenser coil, parallel to the evaporator coil and at a distance of about 5 cm. The dehumidified air is then discharged. The power of the unit is about 1/8 HP (about 95 watt); the actual energy consumption and the conditions of the inlet air have been measured and correlated with the amount of condensed water.

10. During a work extended for about one year in Bari, on the roof of a building near the sea, the following results have been obtained:

a) The electric energy consumption of the device was about 110 ♦ 10 watt-hours/hour and was independent from the amount of separated water.

b) The amount of water separated from the air depends on the physical conditions of the air itself; the water production paralleled the values of the relative humidity.

c) With the particular experimental unit used in this work, water condensation is observed when the relative humidity is more than 50%, independently from the dry-bulb air temperature.

d) Usually the amount of water recovered from the air was about 10 to 20 liters per week, the specific energy consumption being in most weeks 1000 to 1500 kcal/liter of condensed water.

e) The electric energy consumption per weight unit of separated water has been, in the best conditions, 1.5 - 2 times the latent heat of condensation of water, therefore several times larger than the mimimum theoretical energy consumption, due to the

latent heat only, in the most favourable mechanical devices, namely 120 kcal/liter of water. The larger energy consumption is due to the poor heat exchange between the cool air, at the outlet of the evaporator coil, and the surface of the condenser coil of the refrigerating machine. In the little dehumidifiers, (1/8 to 1 HP), in fact, the air speed is rather high, of the order of 200-400 m^3/hour, and such speeds do not allow a good heat exchange and a good recovery of the sensible heat.

f) When the dry-bulb temperature of the inlet air is lower than 10°C, ice formation is observed on the surface of the evaporator coil.

11. The present results suggest some consideretions:

a) The energy consumption in the extraction of water from the atmosphere is such that it does not seem convenient to use this method for obtaining large amounts of water in the arid lands.

b) In emergency conditions, when rather limited amounts of water are needed for the survival of families or groups of persons in arid lands and no source of water at all is available, the extraction of water from the atmosphere may be used if rather high values of relative humidity are observed, at least in some hours of the day.

c) The experimental results suggest the design of more efficient devices for condensing water from the atmosphere; such new devices should have a very good heat exchange and recovery of sensible heat from the dehumidified air.

d) Studies must be carried on the use of wast energy (e.g. of the extra energy of motor cars) for operating mechanical dehumidifiers, and on the use of wind energy, which is directly a source of mechanical energy and which brings the air on the cooling elements of the wind-driven refrigerating machines seems attractive as a system for using heat for cooling air and separating water.

e) Considerable more researches are needed for a better understanding of the phenomena related to natural water condensation after cooling of the air through nocturnal radiation or artificial devices; from such basic studies it is possible to develop practical systems for the production of water for the arid lands.

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Agenda Item: A.4.2.3

United States of America

RECENT DEVELOPMENTS IN THE DESIGN OF SMALL REFINERIES

By R.E. BITTNER,
G.P. BAUMANN,
and A.R. CROSBY,

Esso Research and Engineering Company,
Madison, New Jersey

Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

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No.690

A.4.2.3.

RECENT DEVELOPMENTS IN THE DESIGN OF SMALL REFINERIES

by

R. E. Bittner, G. P. Baumann, A. R. Crosby

Esso Research and Engineering Company

Madison, New Jersey

1. It should be the aim of all concerned that the economic development of a less developed area be handled in a manner that it will be self-sustaining and preferably self-generating. The key to this is that it produce products and services which are competitive with those available from elsewhere. An essential ingredient of such a development is energy, and thus the energy requirements must, in turn, be met in such a way as to be competitive. As the economy of less developed areas grows and the demand for energy grows, petroleum fuel products are relied upon in most instances to meet the energy needs. The problem of furnishing these products to the economy of less developed areas in an economic and competitive manner is the subject of this paper.

2. There are two routes which can be followed to do this:

(a) Import of finished petroleum products.
(b) Manufacture of such products locally from indigenous or imported crudes.

The advantages of off-taking and importing products from large, centralized refining installations are axiomatic. The cost of energy supplied by this route will be competitive since such products must be priced basically competitively through the free marketing areas. On the other hand, the route of manufacturing indigenously is not so clear-cut and is fraught with difficulties. Even though crude oil is purchased at competitive prices, the problem lies in the cost of manufacturing products from these crudes.

3. The difficulty arises from the fact that local requirements for products in a less developed area are small--extremely small, in fact--compared to the cumulative product take-off at the large refining facilities from which competitive areas may be obtaining their requirements. Unfortunately, large refineries are not really multiples of small units, but consist of essentially the same pieces of equipment built in larger sizes. Increases in capacity by this route can be obtained at relatively little increased cost and thus the cost of refineries is not proportional to size; rather, the cost increases more slowly than the size increases. Consequently, the larger refineries inherently require less investment and less operating costs per barrel of refined product. This puts the less developed areas, with their small requirements, at a great disadvantage when going the route of indigenous refining.

4. Sometimes there are compelling reasons for the indigenous refining route--to establish a local industry, relieve unemployment, conserve foreign exchange, etc. Tremendous incentives then exist to overcome the size disadvantage described above. It is possible to overcome the inherent size disadvantage and, as a target, make these installations truly competitive. Considerable effort has been spent

in developing principles and concepts which would permit the installation of very small refineries which would meet this target. Many of these principles have been demonstrated conclusively in recent installations, in which the so-called "divisor advantage" of large refineries has been completely eliminated.

5. The solution worked out in simplest terms was to treat small refineries differently from large refineries from both conceptual and engineering standpoints. The first step was to uncover the factors which established the cost of the small refineries. An analysis of many industry refineries showed that the key cost factors could be grouped into two broad categories. The first encompasses those factors or decisions which set the basis for the refinery design--these have been called "design basis decisions." The second category includes the factors and decisions made by the engineers who design and construct the refinery--these are called "technical decisions."

6. Very small refineries, for the purposes of this paper, are considered to be in the range of 2500 to 5000 B/D of products and should be capable of producing satisfactory products, both in yields and quality. The quality and quantity of such products may vary considerably, depending on the location and needs, and on the quality of the crude which can be made available. In terms of physical facilities, a refinery is considered to encompass the functions of crude receipt and storage, converting the crude into finished blend stocks, blending these into finished products, and storing and loading of products for shipment. Utilities, shops, and other associated facilities are also included within the scope of the term.

7. studies show clearly that the design basis decisions exert a major effect on refinery investment and it is imperative that the effect of such decisions on refinery investment be determined before investment decisions are made. The nature of these decisions and the influence of these on refining investment costs as determined from actual experience are covered below and in Figure 1. Figure 1 shows that a potential savings of 35% can be obtained if all these areas are decided in such a way as to be favorable to the manufacturing function and if such decisions are exploited by aggressive engineering. In most cases, a good portion of the savings can be captured.

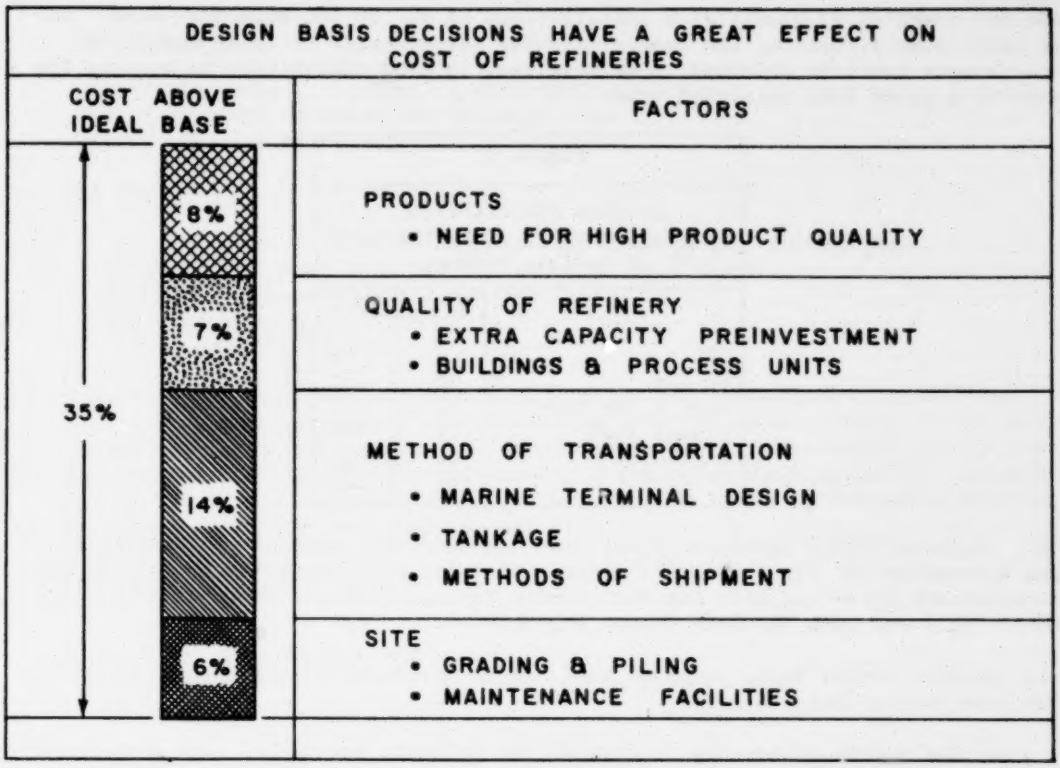
(a) Products - This includes the amount and quality of each product, all of which influence the nature and severity of the process facilities, as well as such items as utility and chemical requirements, materials of construction, etc.

(b) Quality of Refinery - This area covers the need for paved roads, nice office building, cafeteria, and other items which are unessential to the operation of the refinery itself; the degree to which risk acceptance is obtained; and the extent to which money is spent to meet future contemplated needs.

(c) Product Movement - Arbitrary decisions in handling of products can have a vast effect on costs. These items involve marine terminal design, railroad sidings, storage volumes, marketing terminals, size of shipments, etc.

(d) Location and Site - These fix the cost of the land; the leveling, grading, and filling; the necessity for piles; the availability of local facilities such as utilities, shops, transportation, etc. Local regulations which cover construction codes and water pollution, customs and taxes, are also extremely important.

FIGURE I.



8. Given a set of carefully established design basis decisions, it then becomes necessary to apply sharp, imaginative engineering to these decisions in order to extract all of the economic potential available. This involves the following areas:

(a) Process Selection - This requires application of the best process to provide the desired product slate; getting the most out of the crude oil at minimum cost.

(b) Process Design - This area translates the process scheme into specifications which define the plants to be erected. This encompasses many engineering decisions - equipment selection and sizing, plant layout, materials of construction, provision for spare equipment, etc.

(c) Construction - This pertains to the translation of specifications into physical plant and requires efficient management and control to achieve optimum cost objectives. Many decisions are involved affecting the detail design, purchasing, and construction of the refinery; e.g., preparation of the many construction drawings, construction planning (manpower schedule), expediting and inspection of materials, construction management, etc.

9. The results of a recent study illustrate the principles outlined above. The study involved building a refinery to market 4800 bbls./day of salable products. Two basic processing schemes were investigated as alternatives through the study: catalytic cracking (gas oils) and Hydroskimming (naphtha catalytic reforming). The 4800 bbls./day of salable products were made with each scheme, but with different product distribution (see

Figure 2). The investments and operating costs of both cases were essentially the same and compared favorably with installations of ca. 50,000 bbls./day size. In any particular situation, the case giving the better match to local marketing requirements could be selected; thus resulting in good flexibility in meeting the needs of a given less developed area.

Figure 2		
Product Distribution Hydroskimming Vs. Cat. Cracking % of Salable Products		
	H/S	C/C
LPG	2	2
Mo Gas	25	31
Kero & Jet Fuel	11	14
Diesel Fuel	24	30
Fuel Oils	38	22
	100	100

10. Since catalytic cracking refineries have been more expensive historically than Hydroskimming, the previous standard catalytic cracking plant (Model IV) was re-engineered in detail with remarkable cost savings (50% of the Model IV investment). This new unit has been termed the Model V.

11. In this design work, an exact scale model of the onsite facilities was made. Some interesting features are:

(a) The entire processing section of the refinery was fitted into a very small area, 80 ft. x 130 ft.

(b) All of the equipment was designed as one integral unit.

(c) All equipment, except the large towers and connecting piping, was skid-mounted.

(d) Packaged utility supply was provided in the unit so that it was self-sufficient from a utilities standpoint.

12. The above illustrates what the engineer can do in a given situation to achieve minimum costs. As indicated earlier, he is greatly helped in this work by the opportunities provided by the Design Basis Decisions. To clarify this picture, it is desirable to classify the many factors and decisions which set the design basis into one of three general categories: "local," "refiner," and "area-site." This classification is arbitrary in that most decisions are influenced by more than one category. Examples of Design Basis Decisions are given below:

(a) "Local"

(i) Industrial planning.
(ii) Emergency storage.
(iii) Special product specifications.
(iv) Customs, duties, taxes.
(v) Labor education or training.
(vi) Pollution regulations.
(vii) Construction codes.
(viii) Amenities.

(b) "Refiner"

(i) Products ... number, quantities, qualities.
(ii) Product movement and shipment size.
(iii) Quality of refinery.

(c) "Area-Site"

(i) Climate ... temperature, rainfall, hurricane, earthquake.
(ii) Site proximity to sea and existing facilities.
(iii) Site elevation, soil bearing.
(iv) Water availability.
(v) Labor availability.

13. The "local" attitudes, desires, regulations, and planning are established principally by the governments. The generation of a favorable climate in which the refiner and his engineers must work is economically sound. One method to achieve this is industrial planning. The allocation or zoning of land areas for industrial development which meet the needs of industry will help create a favorable climate. Such needs for a refinery are proximity to:

(a) Transportation

(i) Sea.
(ii) Docks (dry and liquid cargo).
(iii) Railroads.
(iv) Roads.

(b) City

(i) Large consuming area.
(ii) Available labor.
(iii) Housing.

(c) Industry

(i) Utilities.
(ii) Shops.
(iii) Chemicals.

Industrial planning can make many of these factors available and attractive. Also, an industrial zone will allow a refinery to be located with other industries so that less self-sufficiency is required.

14. The government's attitude and regulations affecting the refinery are also important. They may, e.g., require additional investment by demands for tankage over and above that required for processing, and for product quality over that actually required. The cost of metering product shipments for customs can vary from a nominal to high, depending on regulations set up by the government. Pollution regulations, construction codes, and amenities vary from location to location. It should go without saying that the refiner is interested in being a good neighbor and in having a safe refinery; therefore, he will automatically adopt safe and satisfactory codes and regulations if none exist. In so far as government codes and regulations are concerned, good ones are those which meet the local requirements and fit the country, refinery site, and size; that is, they are not adopted arbitrarily from elsewhere.

15. The small refiner must think and operate differently from the large refiner. The construction and operation of a small refinery must be turned to advantage. He must make use of the favorable fact that fewer and less sophisticated products are required in a less developed country. On the whole, decisions concerning the number, quantity, and quality of the products required establish the type, amount, and severity of processing. If the number of products are not low, he will be fettered with excessive investment--because each product requires, as a minimum, individual handling for storage, loading, and shipment. Also, he may find it desirable to import certain finished products to avoid inordinate processing costs. In this case, he can obtain a more economical plant and avoid excess products.

16. The refiner must also consider the quality of the refinery. Here again, the small size can be turned into an advantage. Optional design factors and pre-investment for flexibility, as well as convenience items and seasonal variations, can be reduced since fewer products are produced. Also, in the small refinery, the degree of risk acceptance can be increased. Risk acceptance refers to continuity of refining as influenced by equipment availability and the impact of the loss of a unit or the refinery if a fire or other catastrophe should occur. It is relatively easy to make up the output of a small refinery by importation of products. Self-sufficiency must be reduced by using facilities such as docks, water supply, electric power, shops, warehouses and offices which are furnished by others or shared with others.

17. The "area" establishes the importance of natural phenomena such as rainfall, temperatures, and presence of hurricanes and earthquakes. These must be accounted for in the design of the facilities. The specific "site" governs the elevation, grading, soil bearing, piling, and layout and can affect air and water pollution facilities. The site proximity to existing facilities and services such as piers, shops, railroads, utilities, and labor also plays a very important role in establishing the degree of self-sufficiency and thus the refinery cost. Every effort by all concerned must be made to have such areas set aside for this use.

18. In short, the "design bases" of a refinery are made up of the numerous decisions formulated by the local government, refiner, and engineer. These decisions are influenced by the area and site. With the variability in such items, the best decision for one location may often be the poorest decision in another location. An example of such a situation is found in the selection of cooling medium in the refinery; air, sea water, and fresh water cooling are each optimum for a particular site and climate.

19. In summary, if reasonable and favorable conditions exist in a country, such conditions being generated to a large extent by the local attitude and government, and if these favorable conditions are vigorously utilized by an experienced engineering organization, there is every reason to believe that the costs of an indigenous small refinery can be brought in line with those of much larger refineries. It is self-evident that the costs will depend on how many factors are favorable, on how well they have been used, and on how well the less favorable decisions are handled. However, it is reasonable to expect - and it has been demonstrated - that small refineries in the size range of 2500/5000 B/D can be built at a cost that compares favorably with the investment of refineries an order of magnitude larger. The operating and product costs will also reflect this investment reduction. It must be recognized that these small refineries are a different breed than the larger refineries and are custom-designed to meet the requirements of less developed countries. This philosophy and approach are essential for success.

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FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item: A. 5. 2. 3

Italy

THE RESEARCH AND STOPING OF A PYRITE BODY, CONCENTRATION AND UTILISATION OF THE EXTRACTED ORE

By Alberto BONETTI,
Engineer

Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

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THE RESEARCH AND STOPING OF A PYRITE BODY : CONCENTRATION AND UTILIZATION OF THE EXTRACTED ORE

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1. Preliminary Remarks

a) The subject we are dealing with is rather general and it does not contain anything new, therefore it should not represent a particular contribution to the purpose of the meeting without pointing out what follows.

b) Amont the characteristics of the underdeveloped countries are the abundance of low cost unskilled labour, the lack of technicians and skilled labour, of primary sources of energy and of easy communications, the absence of the essential infrastructures.

c) As a consequence, we see the tendency of industry to start in the same way as all the industries once started and to repeat the same process of development they had in a world where competition is not the old one and where a wrong start can mean the end of the industry or the survival in the underdeveloped country of the same social and economic back conditions.

d) In Italy, the pyrite industry, as a consequence of the strong competition existing in the sulphur market is an obvious example; recently one of the main Italian producers felt the necessity to transform radically the methods of the concentration and utilization of the mineral mined from the largest Italian pyrite field reorganizing, in the meanwhile, the structures of the mines.

e) Therefore, when laying out a mining industry in a regime of competition like the pyrite one, the infrastructures of the mine and those of the utilization of the mineral, must be based on the most advanced concepts of the modern technique. The abundance and the low cost of labour must not induce us to repeat the historial process of development; even if at the beginning it is possible or necessary to substitute the use of very expensive equipment by employing hands at low cost, the laying down of the research and mining programme must consider the future use of the above equipment in such a way that a possible and preferable technical development should not cause difficulties, but be a natural and gradual transformation.

2. Exploration and research

a) The utilization of the most up-to-date methods to obtain an exact evaluation of the mine body and the knowledge of its genesis are considered to be of essential importance. There are examples showing that the initial incomplete knowledge of a body has been the cause of an incorrect mine research programme and organization of extraction infrastructures, haulage and stoping. A mine even though of small size or attractive because of favourable outcrops, must not be started unless the geology and the mineralogy of the zone has been studied in advance. This procedure implies the use of a special geological team charged to ascertain the zones requiries the help of photogelogical and geophysical prospecting as the introduction to the mechanical research (by drilling).

b) The object of the geological prospecting, besides the interpretation of the mineralization genesis, must be the identification of the main structures, the soil where the mineralization took place, the identification of the hydrostatic level and permeability of the rocks, the existence of water bearing levels of a different nature. Among the various geophysical methods that can be used, if the results are very cautiously interpreted, is the spontaneous electric polarization method, the resistivity methods and so on for the investigation on ore concentration, and seismics or gravimetrics methods for the interpretation of the large structures.

c) The above operations should be completed by direct exploration through mechanical boring carried out in conformity with a scheduled plan which has to be entirely and in the shortest time fulfilled in order to reduce the capital cost, in accordance with the correlation requirements of drillings to locate the following ones.

This work too must be carried out by firms very skilful in drilling operations.

d) The results obtained should lead to the geologist and to the mining engineer indentifying the mineralization process and its dimensions regarding planimetry and depth. The use of stereographic representation of the mine body, realized by assembling sections on vertical or horizontal planes made of transparent materiel will be made easy by tridimensional vision of the same and the mining technician will be enabled to lay down in a more rational way the first tracks of access to the mine body and the main ways for the extraction, ventilation and education.

e) There are still many Italian pyrite mines, which started their activity without having a complete knowledge of the body and developed from the first outcrops, using a large number of workers and a mining equipment strictly proportional to the requirements of that time. These mines are now heavy burden because they are unable to meet higher output demands and are inadequate in depth and for any extensive developments of the mineralization.

f) Therefore a perfect knowledge of the mine body is required in order to fix the structure of the mine in such a way as is required by the consistence of the mineralization.

Access to the mine body, mining works for the stoping

a) If, by the above mining study, it has been possible to identify the mine body, and the preliminary planning of the whole frame concerning the future mine, can be decided the time required for the various works fixed, and the priority given to those regarding access to the direct identification of the mineralization. These works must be carried out according to a plan considering future and not only present requirements. In this way every mining work is of immediate usefulness as per planned priorities and at the same time is a part of the mine projected to meet future requirements. This is valid for all the installations, externals included.

b) The starting of the operations can be performed by using self-contained temporary equipment (motor generator units, mobile motor compressors and so on). If it is possible to construct two access ways to the mine (shafts, manways or through seams at various levels) and two galleries forming the extraction unit, air inlet and the flow back and services unit; the temporary equipment should be preferably installed in the zone of the services so that their use may be prolonged and be useful, besides the identification and the layout of the most important part of the underground system, during the following stage and at the beginning of this particularly.

   In the meantime the final erection of the extraction structures and of the installations which consequently should not be disturbed, during the prospecting and development stage, should be carried on.

c) The size of the shafts and their galleries must consider the full mine development as per the preliminary planning even if the body is initially exploited in its nearest and more approachable parts.

   This planning must duly consider mechanization requirements, either in fixing the section and the layout of the galleries in order to permit the passage of heavy locomotives and the installation of belt conveyers, or in the timbering, to put them in a position to support the high speeds and heavy loads of a skip required for up-to-date extraction.

   From the very beginning, therefore, the use of wagons having a large carrying capacity should be advantageous as they would always make possible eventual increasing of production and realize the best stopes and transport efficiency even if these operations would have to be at first carried out by hand.

d) The final external installations (transformation cabin, compression station, workshops and stores) must adapt to easy enlargement for setting up other installations of the same kind and, this choice, therefore, must consider this eventuality and its convenience.

   The excavation and loading equipment should be chosen after investigation on the industrial market giving the preference to those requiring a reduced maintenance and having up-to-date technical features.

e) The experience of the work carried out in the Italian pyrite mines suggests the use of hammer drills air leg mounted dulls weighing from kg. 21 to kg. 25, mechanical cutters with operating capacity of 50/60 tons per hour and scraper from 30 to 50 HP. These simple machines are by now of general use and they permit the employment of semi-skilled labour and are useful in carrying out works of secondary importance in time of high mechanisation too.

4. Stoping methods

a) The particular research performed through the preliminary mining works, should have completed determinations concerning the static characteristics of the mine body, the hardness and compactness of the ore for mining purposes, the collapsing degree of the rocks. The type and the trend of the mineralization should also have been determined. On the basis of the above knowledge must be chosenthe stoping method which has been already outlined when projecting the main structures.

b) It is possible to classify suitable methods in conformity with the type of mine body. These methods may change if the mine body is of lenticular or bedded type having its main dimensions in two directions, or if the type is the so called "shoot" having three directions of equivalent dimensions or in accordance with its inclination.

c) The examination of the above mentioned conditions should make it possible to know if the method to adopt is with gob or not.

This decision must be carefully taken because it implies a different organization of the whole mine; if there are doubts on the use of the gob method, a new organization scheduling it is essential, so that any eventual change should be made under more favourable conditions.

d) Among stoping methods employing a large number of hands without being obliged to make use of special mechanical equipment we mention the rising reverse bench carried out by gradual and continuous excavations or serially the store chamber first and its filling next. The waste filling is located in the dump and can be carried out with hand tilted wagons; its transformation into a mechanical unit can be made without altering the stoping method, using a dumper or a scraper. The stopes have generally large dimensions and are suitable to the introduction of machines.

When the pyrite extracted in stopes using the reverse bench or store chamber method is of normal compactness we can obtain, gob included, a yield of 8/10 tons per man and there is a chance of raising it, after having mechanized the loading of the ore and the unloading of the gob, to 20/25 tons per man. To use these methods a compacted ore and a rather hard back is essential.

e) Where it is possible to work avoiding the waste filling method, and the back is rather solid, and the stopings in a position the use the scraper to carry on the stoping and the mining, obtain

the best results. We may classify among these methods, that concerning retiring underlevels suitable to the case of a sub-vertical stratified body or that concerning parallel slants the central as a scrapering unit and the lateral ones as drilling and anchorage for pulley transmissions units. This last method, first used in the S. Giovanni Rotondo's bauxite mines has been applied in the pyrites of Niccioleta and the Isle of Elba. The yield vary from 12 tons per man during the development to 25/28 tons per man during the stoping stage. The mechanical installations are reduced to a few scrapers, 3 calf wheels of 50/80 HP and pneumatic drills. This method is more suitable in case of regular strata having a slight inclination and less than 6/8 metres thickness. These above mentioned methods require a limited equipment and they give a height rate of production, therefore they should be always used even in the case of the productive transformation of the mine.

f) A particular consideration is due to the case of the shoot mine bodies formed by friable ore and an example is given by a big Tuscan mine. A rising stoping is not possible because of the liability of the ore to fall in; therefore the whole removal and the replacement of the body is carried out by using the gob and slope stoping by the near-side cuts method. Considering that the difficulty in settling the gob by hand and the slowness in carrying on this operation would require a productivity reduction of the yards the use of the pneumatic system is advisable to settle the matter and to obtain a sufficient degree of solidity in order to permit the passage of the successive stopings under the gob. The above operations require considerable external compression installations as well as an internal system of regular distribution of the gob to the machines. To make up for it, high filling potentialities per hour may be achieved so that remarkable yard productions are obtained. Therefore, in the case above described, even if the starting of the stoping may be carried out using the hand gob method, the structure of the mine must secure an easy arrival of the material from the exterior and an easy distribution along the gangway to make possible the future mechanization of the gob.

5. Dressing and transportation means

a) The mined pyrite must be removed and conveyed to the industrial utilization. After having considered the distance from the mine to the utilization places and the road conditions, a decision concerning the advisability of a preliminary concentration in accordance with the content of the mined ore has to be taken. Normally the concentrations of nearly pure ore are frequent in pyrite mine bodies and it is a rule to separate the extraction of the rich pyrite from that intermixed with waste; rich pyrite is that having a commercial content (more than 47 % of sulphur). Therefore the concentration problem concerns only a part of the whole production, but the crushing of the whole production under 12 mm., is required.

b) The dressing is generally carried out by crushing, classification and washing by hydrogravimetric machines, largely using Symons type conical crushers, vibrating screens and sieves. The vanners once used for the best ore have been everywhere replaced by flotation equipment for the tailings which can recover the rich sediments coming from the crushing by the wet method. Hydrocyclones and Dorr thickeners are often used for thickening.

c) The operating and maintenance cost of this dressing is about $ 0.20/0.25 per ton of crushed ore, $ 0.50/0.75 per ton of washed ore, $ 1.20/1.40 per ton of ore already passed in flotation. By these installations a commercial production having 48/49 % of sulphur may be achieved.

The installation cost for crushing equipment is about $ 150 per ton of ore dressed per 16 hours, washing machines about $ 500 per ton of ore washed per 16 hours, flotation equipment $ 1,400/1,500 per ton dressed per 24 hours.

d) For workshop services, water supply, electric energy required by the above installations, the first thing to examine is the possibility of centralizing the ore dressing which may be carried out, if there are some mines not far off, either in one of these or in the ore utilization site if the starting of a utilizing industry takes place in the same producing Country, In this connection must be pointed out that pyrites, until now considered as a sulphur ore, is going to lose more and more its importance in the world market because of the costantly increasing production of regenerated sulphur in addition to the natural production at low cost of this metalloid.

e) Consequently we shall have to increase the pyrite utilization as iron ore, and as a consequence of this change the concentration methods until now used (above described and planned to obtain a sufficient sulphur content in order to reduce ore transport cost) are no longer in a position to obtain a better iron or utilization.

f) Following this different trend, in Tuscany, in the largest extractive pyrite body, has been erected a big centralized installation for the utilization of the pyrite as soon as extracted, without concentration process, to obtain sulphur acid and electric power, as by products of iron pellets at 66 % Fe; so that in this way, high contents are obtained through a utilization process directly carried out on ashes coming from pyrite furnaces. It is advisable to bear in mind these new trends which practically are imposed by the situation of the sulphur market.

Conclusions

a) The subject dealt with is too wide to be entirely developed by this short note.
We wanted to draw attention to the necessity, when facing the various problems concerning the research and the stoping of a pyrite body, even if there are favourable conditions for the large use of labour, to foresee an eventual mechanization and to plan the mine in the same way as if its starting had taken place in a developed country.

b) Besides we reported on the new trends concerning the concentration and the utilization of pyrites as they are of main importance in planning a new industry in a country not engaged with traditional markets.

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UNITED NATIONS CONFERENCE
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Agenda Item: A. 5. 2. 1

United States of America

SUCCESSFUL NEW TECHNIQUES IN PROSPECTING FOR PHOSPHATE DEPOSITS

By Vincent E. McKELVEY,
Assistant Chief Geologist,
U. S. Geological Survey,
Washington, D. C.

Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

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SUCCESSFUL NEW TECHNIQUES IN PROSPECTING FOR PHOSPHATE DEPOSITS1/

A.5.2.1

by
Vincent E. McKelvey, Assistant Chief Geologist
U. S. Geological Survey
Washington, D.C.

1. Two decades ago, phosphorus was called the bottleneck in alleviating the world's hunger. South America, Asia, and other large areas of the world were thought to have no important local sources of this vital nutrient. The outlook now is much brighter, partly because a few important new deposits have been developed, but mainly because technological and geological advances promise to make phosphate even more widely available in the future.

2. Among these advances, four in the fields of beneficiation and fertilizer technology are of special significance: 1) A variety of washing and flotation techniques make it possible now to produce marketable concentrates from unconsolidated deposits that contain only 5 to 10 percent P_2O_5 (see Ruhlman, 1958, p.10). 2) Newly developed phosphate fertilizers either do not require sulfuric acid or require less than is currently used in making the ordinary varieties of superphosphate, and hence can be manufactured where sulfuric acid is in short supply (Walthall, 1953, p. 205). 3) Certain phosphorites, apparently ones relatively high in hydroxylapatite, have been found to be relatively soluble in soil solutions (as judged by their neutral ammonium citrate solubility); they can therefore be used directly as fertilizers on many soils without prior treatment and hence can be marketed at low cost. Examples are the Curaçao Island deposits, certain of the North African deposits (Jacob and Hill, 1953, p. 336), and the newly discovered phosphorites of the Sechura Desert, Peru (T. M. Cheney, written communication, 1961). 4) Experiments at the Instituto de Pesquisas Agronomicas of Brazil, undertaken in cooperation with technicians of the U.S. Agency for International Development, indicate that common phosphorites, which are relatively insoluble where applied to most soils in temperate climates, can be used directly on acid soils of the tropics (J.L. Haynes, written communication, October 1961). All these developments will help increase the geographic availability and lower the cost of phosphate fertilizers.

3. Equally important in increasing the geographic availability of phosphorite are gains in knowledge of the origin of marine phosphorites. These gains result from extensive studies of the Permian Phosphoria Formation of the western United States (see McKelvey and others, 1953 and 1959) and from analysis of the modern marine environment in which phosphorites are forming (Kazakov, 1937; Brongersma-Sanders, 1957; McKelvey and others, 1953; and McKelvey, 1959). This improved understanding of the origin and occurrence of marine phosphorites provides clues useful in prospecting, for it makes it possible to recognize geographic provinces and geologic formations that are favorable for the occurrence of an important class of phosphorites. It is this topic--geologic clues useful in prospecting, and the genetic basis for them--that is the principal target of this discussion.

Origin and environment of deposition of marine phosphorites

4. The solubility of phosphate in sea water increases with decreasing pH and temperature (Sverdrup and others, 1946, p. 241 and 788), and for this reason it is most concentrated in deep cold waters. Oceanic circulation (a reflection of atmospheric circulation brought about by solar heating combined with the rotation of the

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earth), however, deep-plows the sea and brings these nutrient-rich waters to the zone of photosynthesis in local areas.

5. In an idealized ocean, the main elements of the current system consist of a large circulating gyral in each hemisphere (figure 1), with water cooled in polar latitudes moving toward the equator along the east edges of the ocean, and water warmed in equatorial latitudes moving poleward (see also Fleming, 1957). In this system, cold nutrient-rich waters are brought to the surface in four situations: 1) Where a current diverges from a coast, or where two currents diverge from each other. The effects of cold currents moving toward the equator in bringing cold phosphate-rich water along the coast are abetted by the seaward movement of coastal surface water that results from the combined effects of prevailing wind and Coriolis force, for as the surface water moves seaward, deep cold water wells up to replace it. 2) Where two currents meet to produce turbulence. 3) Along the west edge of poleward-moving density currents. And 4) in high latitudes where highly saline water from the tropics tends to sink as a result of winter cooling (figure 1).

6. Pronounced climatic, biologic, and geologic effects accompany this deep-plowing of the sea, especially in the areas of upwelling produced by divergence. The presence of cold waters along coasts produces coastal fogs and humid-air deserts. Some of the driest areas in the world are of this type--humid air, perhaps some hygrophytic vegetation, but no rain. The Peruvian and southwest African deserts are present-day examples.

7. The naturally fertilized waters that lie alongside these deserts are the lushest gardens of the sea, for the upwelling cold waters there support tremendous quantities of organisms (see Sverdrup and others, 1946, p. 786-787), with diatoms and other phytoplankton at one end of the food chain, and fish, whales, and fish-eating sea fowl at the other. Blooms of dinoflagellates (red tides) and diatoms are characteristic biologic phenomena in upwelling areas, as are the mass mortalities of fish that accompany red tides and may be a consequence of them (Brongersma-Sanders, 1957).

8. The geologic phenomena accompanying upwelling are perhaps most complex of all. Phosphate in the upwelling water becomes less soluble as the pH and temperature increase near the surface and is precipitated either inorganically or biochemically. Some of the organic matter produced in the zone of photosynthesis is winnowed away and dispersed or destroyed by surface currents, but much of it settles to the bottom, producing reducing conditions even along the open sea. Silica is precipitated biochemically through diatoms, silicoflagellates, and sponges; carbonates are precipitated either chemically or biochemically in warmer coastal waters; and salines may form in lagoons that extend into the adjacent deserts. And, of course, guano and guanotized rock are also characteristic deposits in this general environment.

9. These several phenomena may be observed today in many areas of upwelling, especially those along the western margins of the continents, and nearly all the phosphate deposits known on the present sea bottom lie in such areas of divergent upwelling (figure 2). The geologic effects are less well known in the modern ocean, however, than they are in ancient sediments, and to illustrate the characteristics of the sediments formed in the upwelling environment we will turn now to the Permian Phosphoria Formation and associated rocks in the western United States.

The phosphorite facies

10. The sedimentary facies that are found in this environment are summarized in figure 3, which represents an idealized section of rocks deposited synchronously in the Phosphoria sea in Idaho and Wyoming. As shown there, dark carbonaceous shale typically grades shoalward into phosphatic shale, phosphorite, and dolomite; chert; several facies of carbonate rock; and saline deposits and light-colored and red shale.

11. Epeirogenic movements cause these environments to shift laterally. As the sea transgresses and regresses, therefore, the lateral sequence shown in figure 3 comes to be reproduced, in whole or in part, in the same or in reverse order in vertical section, and over the region as a whole shoalward facies overlap and intertongue with deeper-water facies in vertical section. An example of such an intertongued sequence of sediments is shown by the reconstructed cross section of the Phosphoria Formation and its stratigraphic equivalents shown in figure 4.

12. The vertical sequence of lithologies is generally not the complete assemblage of sediments shown in figure 3, nor in exactly the same order shown there, but may be interrupted locally by interbedding of other lithologies. The horizontal sequence too is seldom as regular or complete as shown in figure 3, for the sea bottom may be much more irregular than that idealized diagram implies.

13. In the main, however, the assemblage illustrated in figures 3 and 4 is typical of marine phosphorites deposited in areas of upwelling associated with divergence. Black shale, phosphorite, and chert (or diatomite or cherty mudstone) are the typical rocks, and the vertical sequence is often not unlike that shown in figure 4. Formations, such as the Miocene Monterey of California, that do not contain much associated limestone may represent deposition at relatively high latitudes where the temperature is too cool to favor precipitation of carbonate rock. And those phosphatic limestones that are not associated with conspicuous amounts of black shale or chert, such as are common in the Miocene of the Gulf Coast, perhaps were deposited in areas of dynamic upwelling or turbulent mixing along the western edge of warm density currents that occur along the west side of the oceans (figure 1). These currents are not as rich in nutrients nor as cold as the upwelling waters formed by divergence, and in low latitudes they create waters favorable for the precipitation of limestone, yet fertile enough to support moderately rich organic growth.

Clues useful in prospecting

14. Knowledge of the genesis, environment of deposition, and facies relations of the phosphorites provides two general kinds of clues useful in prospecting, one that we might call oceanographic, the other geologic or stratigraphic.

15. The oceanographic clues are based on the distribution of upwelling in modern seas. Because of the relative stability of many continental margins since late Mesozoic time, ocean currents have also been relatively stable. Many areas of present-day upwelling are therefore clues to the general location of upwelling in late Mesozoic and Cenozoic time, and suggest the occurrence of phosphate deposits in rocks and beach sands of adjacent coastal regions. The known phosphate deposits of California, Baja California, Venezuela, Morocco, Senegal, and Angola are examples of such deposits; the phosphate deposits recently discovered by George Nicol in the Sechura Desert of Peru were found by using this approach. One might expect that a search for phosphorites in the vicinity of other areas of modern upwelling would be rewarding--for example, in Chile, Southwest Africa, Dahomey, the Ivory Coast, Rio de Oro, and countries in the vicinity of the Arabian Sea.

16. The present sea bottom in areas of upwelling also contains phosphate deposits that perhaps can be recovered by dredging (Mero, 1961). Very likely most guano deposits in the vicinity of upwelling have been discovered already, but phosphatized rocks formed from the leaching of older guano deposits, that are themselves now wholly destroyed, have been less well prospected.

17. The geologic clues helpful in searching for phosphate deposits are those furnished by the presence of companion members of the phosphorite family, principally black bituminous shale and chert or other siliceous rocks. Almost any marine black bituminous shale or bedded chert (generally excepting those cherts that are interbedded with volcanic rocks or other thick eugeosynclinal sequences of sediments) may be presumed to have associated phosphorite or phosphatic shale, although perhaps not in deposits of mineable thickness or quality. Analysis of regional lithofacies relations may make it possible to use other members of the family of sediments shown on figure 3--red beds and salines, for example--to identify the horizons that may be laterally favorable for the occurrence of phosphorite.

18. A sparkling example of the application of the geologic approach to prospecting is afforded by R. P. Sheldon's discovery of phosphorite in the Upper Cretaceous sediments of the Gaziantep region of Turkey in August 1962. Sheldon, working under a U. S. Geological Survey project sponsored by the Government of Turkey and the U. S. Agency for International Development, began his search for phosphate with a search of the literature in an analysis of paleogeographic and lithofacies relations in Turkey, next

examined gamma-ray well logs in an attempt to identify specific phosphate-bearing horizons, and then studied in the field the favorable areas and horizons so defined.

19. Sheldon's use of gamma-ray logs deserves special mention, for it illustrates a tool useful in prospecting unexplored terranes. Most marine phosphorites contain 0.005 to 0.02 percent uranium, enough to be detected not only in gamma-ray well logs but also, under favorable circumstances, by aerial radiometric reconnaissance. However, the phosphorites rich in hydroxylapatite (Sechura, Peru, for example) and most guanotized rocks generally contain little or no uranium, so this method may not be applicable to them.

20. In phosphorite prospecting it is worth stressing that many phosphorites, especially those associated with black shales, are likely to be concealed or, at best, poorly exposed, and must be prospected by trenching or test-pitting. Moreover, phosphorite is not a highly distinctive rock, and those not familiar with its appearance may overlook it in hand specimen or outcrop. One valuable aid in identifying it in the field is that the phosphatic grains are generally pelletal, oolitic, nodular, or pisolitic. A simple and generally reliable field test is that a few drops of concentrated hydrochloric acid on rocks containing more than 5 to 10 percent P_2O_5 will produce a white spot, the density of which is roughly proportional to the phosphate content (Gardner, 1944, p. 16). A similar coating or bloom often forms naturally on weathered surfaces. Semiquantitative analyses of phosphate may be made in the field by the method described by Shapiro (1952).

21. In addition to the marine phosphorites deposited in the upwelling environment, other kinds of phosphate deposits are economically important, and are probably more abundant than heretofore recognized. The phosphatized rocks derived from guano have already been mentioned; other important types are residual phosphate deposits, including those concentrated at ancient unconformities, and apatite deposits of igneous origin which are commonly associated with alkalic intrusives. Areas favorable for the occurrence of minable phosphate deposits are widespread, and we may fully expect more intensive prospecting to increase the availability of this vital nutrient in many areas of the world.

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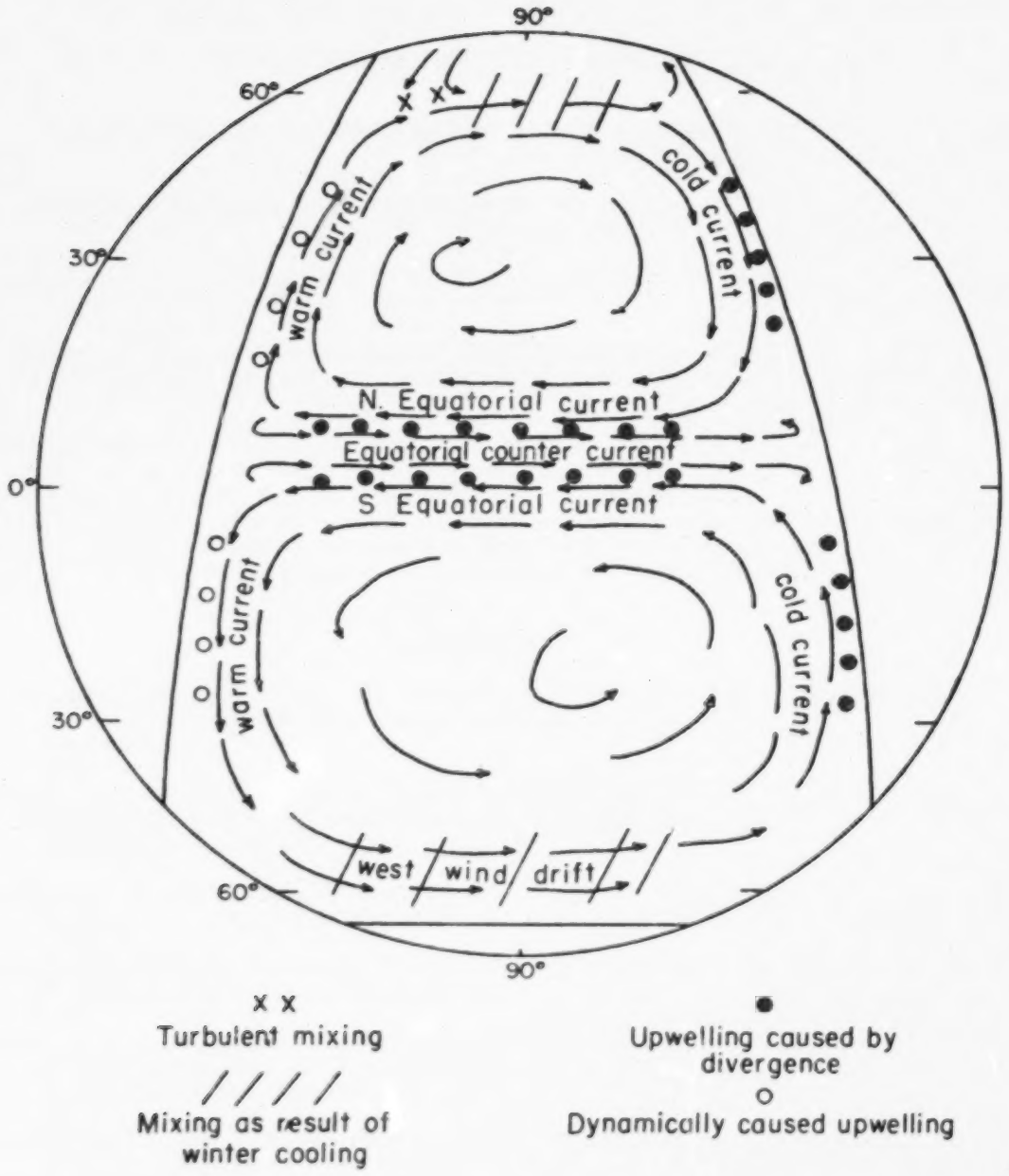

Figure I - Surface currents in an idealized ocean, showing areas of ascending, nutrient - rich water (See Fleming, 1957)

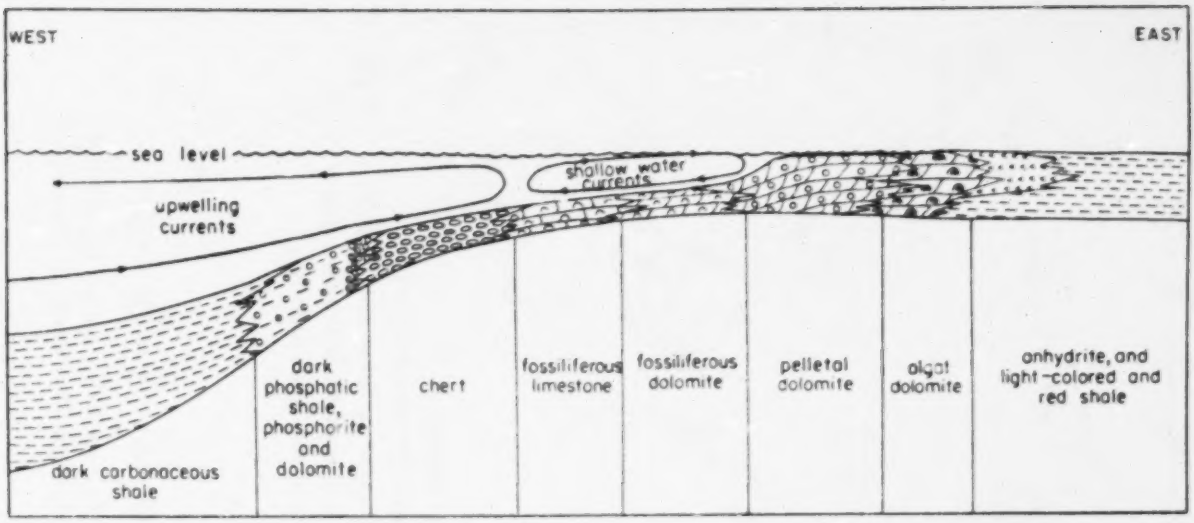

Figure III - Lateral sequence of environments and sediments in the Phosphoria sea (Cheney and Sheldon, 1959)

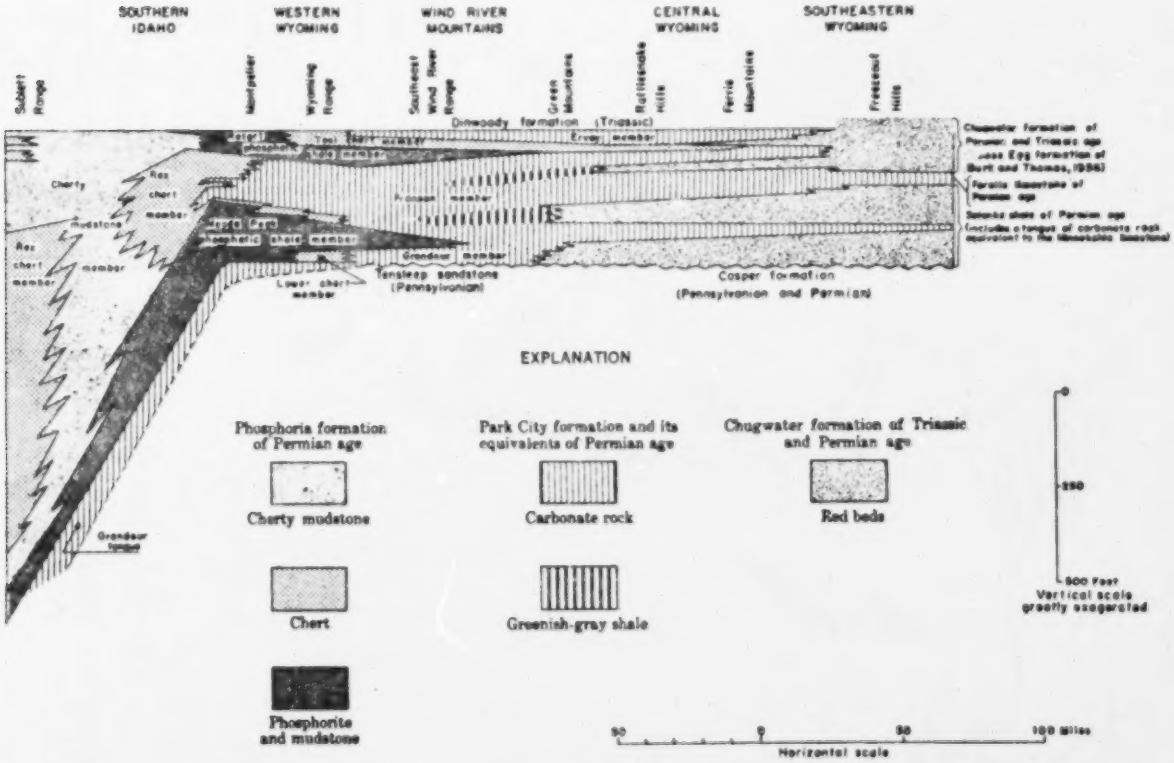

Figure IV - Stratigraphic relations of the Phosphoria, Park City, and Chugwater formations in Idaho and Wyoming (McKelvey and others, 1959).

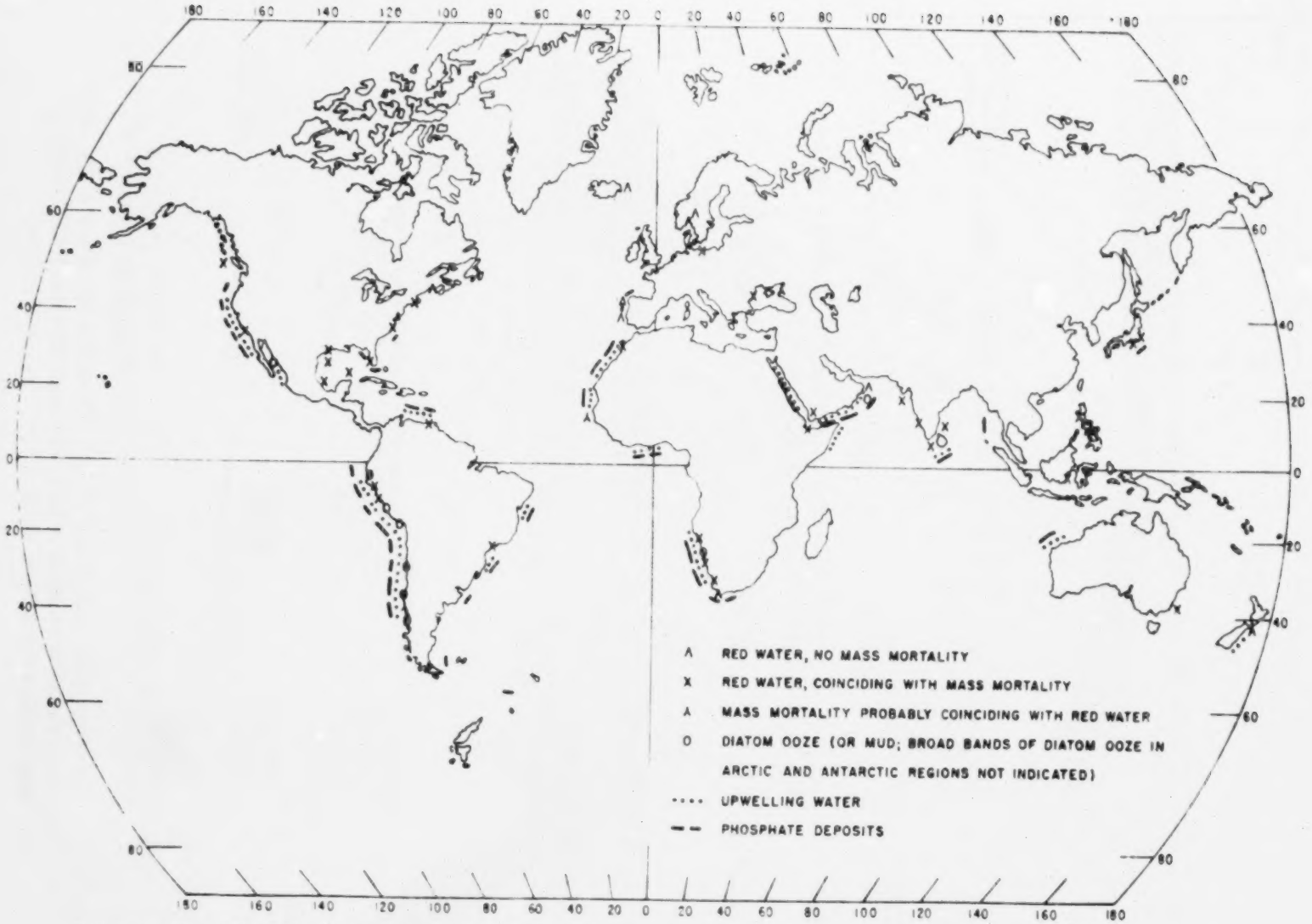
A RED WATER, NO MASS MORTALITY
X RED WATER, COINCIDING WITH MASS MORTALITY
A MASS MORTALITY PROBABLY COINCIDING WITH RED WATER
O DIATOM OOZE (OR MUD; BROAD BANDS OF DIATOM OOZE IN ARCTIC AND ANTARCTIC REGIONS NOT INDICATED)
UPWELLING WATER
PHOSPHATE DEPOSITS

Figure II - Distribution of upwelling water and related phenomena in modern oceans (modified Brongersma-Sanders, 1957, to include data on the distribution of phosphate deposits)

1737 E - Nov. 1962 - 1,600